

S/Sgt 71

Reference

DEPARTMENT OF THE ARMY
FIELD MANUAL

FM 5-35

DEPARTMENT OF THE
AIR FORCE MANUAL

AFM 88-54

ENGINEERS' REFERENCE AND LOGISTICAL DATA



DEPARTMENTS OF THE ARMY AND THE AIR FORCE
FEBRUARY 1960

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Portions of paragraph 165 and 169, Tables 171 and 187, from American Concrete Institute, May 1956, paragraph 506 and 1303. Building Code Requirements for Reinforced Concrete, 5th printing pages 22 and 23; formula 30 on page 96; Table 9 on page 52; diagram 17 on page 58 and Table 15 on page 57 of the Reinforced Concrete Design Handbook, 2d edition, from American Concrete Institute.

Figure 46, from Section 20, page 311, Nomogram for Calculating Pipe Size, discharge and head loss, American Pipe Manual, from American Cast Iron Pipe Company.

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No. 5-35
AIR FORCE MANUAL
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DEPARTMENTS OF THE ARMY
AND THE AIR FORCE

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CHAPTER 1

INTRODUCTION

1. Purpose

This manual is intended to provide engineer and other military personnel at all levels, including operations and planning officers, with a compilation of data for use as a guide in the logistical planning of engineer activities.

2. Scope

a. The manual includes logistical data pertaining to engineer troops, equipment, materials, and installations, and to all types of engineer activities, including fortifications, camouflage, roads, railroads, bridges, airfields, utilities, and general construction. It also contains miscellaneous physical and mathematical data and conversion tables.

b. The material presented herein is applicable without modification to both nuclear and non-nuclear warfare.

3. Relation to Other Manuals

Various manuals of the FM 5-, TM 5-, and AFM 88-series contain detailed logistical data on the above topics, and on individual items of engineer equipment in temperate climates. This manual is confined to summarizing such information and stating what sources should be consulted for further details.

CHAPTER 2

ENGINEER TROOPS

4. General

FM 5-5 sets forth the mission, assignments, capabilities, organization, and normal employment of all engineer troop units. The TOE's for these units give further personnel and equipment details.

5. Strength of Engineer Units

The tabulation in table 1 gives basic data on engineer troop units; that in table 2, on engineer teams listed in TOE 5-500C. The data is subject to change and the latest appropriate TOE list should also be consulted.

Table 1. Engineer Troop Units

TOE No.	Unit	Authorized strength				Normal assignment	Mission, capabilities, and remarks
		Off	WO	EM	Total		
	ENGINEER COMMAND UNITS						
5-301	Headquarters and headquarters company, engineer brigade.	29	6	107	142	Communications zone, task force, army, or high headquarters.	Commands engineer units totaling 9,000 to 15,000 men.
	ENGINEER COMBAT UNITS						
5-15	Infantry division engineer battalion.	42	4	739	785	Infantry division-----	Provides general engineer support for infantry division. Combat companies can operate independently.
5-16	Headquarters and headquarters company, infantry division engineer battalion.	22	4	224	250	1 per battalion-----	Provides division engineer special staff and command staff, communication, reconnaissance, supply, maintenance, and supplemental heavy equipment for the infantry division engineer battalion.
5-17	Engineer company, infantry division, engineer battalion.	4	0	103	107	5 per battalion-----	Provides general engineer support for infantry division. Combat companies can operate independently.
5-35	Engineer combat battalion, army.	30	3	586	619	3 per engineer combat group.	As component of engineer combat group, provides general engineer support for a corps or army. Combat battalions can operate independently.

Table 1. *Engineer Troop Units—Continued*

TOE No.	Unit	Authorized strength				Normal assignment	Mission, capabilities, and remarks
		Off	WO	EM	Total		
5-36	Headquarters and headquarters and service company, engineer combat battalion, army.	15	3	139	157	1 per battalion-----	Provides command and staff, communications, reconnaissance, supply, maintenance, and supplemental equipment for the engineer combat battalion, army.
5-37	Engineer combat company, army.	5	0	149	154	3 per battalion-----	Provides an operating component of the engineer combat battalion for performance of general engineer work contributing to combat effectiveness of corps and army.
5-67	Engineer water supply company.	5	0	105	110	1 per field army or 1 per 400,000 troops in communications zone.	Can produce 27,000 gallons per day of potable water; transport 18,000 gallons in one lift.
5-96	Headquarters and headquarters detachment, engineer camouflage battalion.	6	3	54	63	Army communications zone.	Provides camouflage support for field army, or equivalent demand in communications zone.
5-97	Engineer camouflage company.	5	0	65	70	3 per battalion or field army.	Provides camouflage support for field army, or equivalent demand in communications zone.
5-137	Engineer panel bridge company.	4	0	124	128	Corps, army-----	Has one 130-foot, 40-ton panel bridge.
5-138	Engineer float bridge company.	8	1	209	218	2 per corps, 9 additional for field army.	Has 700 feet of M4T6 bridge or 10-four-float M4T6 rafts or combinations of bridges and rafts.

5-192	Engineer combat group.	16	1	64	81	2 per corps; 3 per field army.	Provides general engineer support for a corps or field army.
5-5	Armored division engineer battalion.	41	4	870	915	Armored division-----	Provides general engineer support for armored division. Armored companies can operate independently. Bridge company has 576 feet of floating bridge.
5-6	Headquarters and headquarters company, armored division engineer battalion.	19	4	188	211	1 per battalion-----	Provides the division engineer special staff section; and command and staff, communication, reconnaissance, supply, and maintenance for the armored division engineer battalion.
5-7	Engineer company, armored division engineer battalion.	5	0	161	166	4 per battalion-----	Provides general engineer support for armored division. Armored companies can operate independently.
5-8	Bridge company, armored division engineer battalion.	6	0	144	150	1 per battalion-----	Provides general engineer support for armored division. Bridge company has 576 feet of floating bridge.
5-225	Airborne engineer battalion.	33	4	627	664	Airborne division-----	Provides general engineer support for airborne division.
5-226	Headquarters and headquarters and service company, airborne engineer battalion.	16	4	163	183	1 per battalion-----	Provides general engineer support for airborne division.
5-227	Airborne engineer company.	5	0	149	154	3 per battalion-----	Provides general engineer support for airborne division.
5-367	Engineer light equipment company.	5	1	180	186	1 per engineer combat group.	Augments group for construction support of a corps or field army.
5-412	Headquarters and headquarters company, engineer aviation group.	15	5	91	111	Engineer aviation brigade, major air force.	Controls 2 to 4 aviation battalions and attached troops.

Table 1. *Engineer Troop Units—Continued*

TOE No.	Unit	Authorized strength				Normal assignment	Mission, capabilities, and remarks
		Off	WO	EM	Total		
5-420	Engineer Amphibious Support Command.	243	43	3, 491	3, 768	1 per theater-----	Provides amphibious planning, assault lift, shore repair control for a corps in amphibious assault.
	ENGINEER CONSTRUCTION UNITS:						
5-312	Headquarters and headquarters company, engineer construction group.	14	3	62	79	Army, communications zone.	Commands 1 to 4 engineer construction battalions and up to 2,000 other engineer troops.
5-324	Engineer dump truck company.	4	1	103	108	Engineer group or brigade.	Operates 48 dump trucks, 5-ton; must be loaded by supported unit; drivers for 2 shifts.
5-328	Engineer heavy equipment company.	4	2	162	168	Engineer group-----	Operates and maintains heavy equipment to augment construction units.
5-329	Engineer port construction company.	7	4	220	231	Army, communications zone.	May be attached to engineer construction group to augment it for port construction; has diving and special equipment including floating equipment.
5-115	Engineer heavy construction battalion.	28	11	751	790	Theater air force, army, communications zone.	All types of heavy construction, with special reference to airfield construction and allied activities.

5-116	Headquarters company, engineer construction battalion.	13	3	100	116	1 per batatlion-----	All types of heavy construction, with special reference to airfield construction and allied activities.
5-117	Engineer service and support company, engineer construction battalion.	3	2	165	170	1 per battalion-----	All types of heavy construction, with special reference to airfield construction and allied activities.
5-118	Engineer construction company.	4	2	162	168	3 per battalion-----	All types of heavy construction, with special reference to airfield construction and allied activities.
5-372	Headquarters and headquarters detachment, engineer pipeline group.	11	5	48	64	1 per theater headquarters.	Prepares plans for bulk petroleum handling systems and commands and supervises pipeline construction and maintenance units.
5-376	Headquarters, headquarters and service company, engineer pipeline battalion.	14	2	70	86	1 per 3 to 5 engineer pipeline companies.	Commands, plans, and supervises the construction, rehabilitation, and field maintenance of petroleum distribution and storage facilities.
5-377	Engineer pipeline company.	5	1	253	259	Headquarters, headquarters and service company, engineer pipeline battalion.	Constructs and rehabilitates petroleum unloading and bulk storage facilities and pipeline systems; partial field maintenance of petroleum pipeline systems.
ENGINEER MAINTENANCE AND SUPPLY UNITS							
5-48	Engineer supply point company.	3	1	98	102	Army or independent corps.	Operates engineer supply point in the corps and army areas. May be used to distribute supplies to a large concentration of construction projects or to operate issue section of a large depot.

Table 1. *Engineer Troop Units—Continued*

TOE No.	Unit	Authorized strength				Normal assignment	Mission, capabilities, and remarks
		Off	WO	EM	Total		
5-157	Engineer field maintenance company.	5	5	188	198	Field army or communications zone. Organic to amphibious support brigade.	Provides engineer field maintenance and parts to supported units for organizational maintenance.
5-262	Headquarters and headquarters company, engineer maintenance and supply group.	15	8	108	131	Army communications zone.	Commands group, normally 2 or more battalions of service troops.
5-266	Headquarters and headquarters detachment, engineer depot battalion.	5	3	38	46	Communications zone.	Commands 2 to 5 depot and other supply companies.
5-267	Engineer depot company.	4	2	195	201	Communications zone.	Operates general engineer supply depot for engineer troops, with labor units attached.
5-278	Engineer depot maintenance company.	4	4	191	199	Maintenance and supply groups in communications zone.	Normally assigned with a parts depot company to support 3 to 4 field maintenance companies.
5-279	Engineer parts depot company.	4	2	172	178	Engineer maintenance and supply group.	Provides parts support for 9,000 items of engineer equipment.
5-387	Engineer forestry company.	4	0	142	146	Communications zone.	Logs timber and operates sawmill; 20 to 40 M. b.m. per day.

5-464	Engineer company, Redstone.	7	0	178	185	1 per U.S. Army missile command (heavy). Organic to field artillery missile group (heavy).	Provides liquid hydrogen and carbon dioxide necessary to support the operations of a REDSTONE missile battalion. Provides field maintenance for engineer equipment of the missile battalion.
ENGINEER TOPOGRAPHIC AND INTELLIGENCE UNITS							
5-55	Engineer topographic battalion, army.	18	8	323	349	Army-----	Provides maps and engineer information as required for an army in the field; prepares and/or reproduces new or existing maps, map substitutes, and engineer intelligence data; stores and distributes maps and similar material required by army or corps troops.
5-56	Headquarters and headquarters company, engineer topographic battalion, army.	10	6	123	139	Organic to engineer topographic battalion, army.	Provides command and staff, supply and maintenance, and engineer survey capability for topographic mapping for the engineer topographic battalion, army. Survey element may carry ground control forward to corps survey elements for artillery requirements.
5-57	Engineer map reproduction and distribution company, army.	4	1	106	111	Organic to engineer topographic battalion, army.	Reproduces, stores, and distributes new and existing maps, photomaps, overlays, and other intelligence material.

Table 1. *Engineer Troop Units—Continued*

TOE No.	Unit	Authorized strength				Normal assignment	Mission, capabilities, and remarks
		Off	WO	EM	Total		
5-59	Engineer photomapping company, army.	4	1	94	99	Organic to engineer topographic battalion, army.	Compiles original, or revises existing, maps and map substitutes; prepares overlays, sketches, drawings, etc.; for reproduction.
5-167	Engineer topographic company, corps.	4	3	107	114	1 per corps-----	Provides map and survey information in support of corps operations.
5-343	Engineer topographic aviation company.	89	1	173	263	Topographic survey group.	Operation and limited maintenance of aircraft supporting large field survey operation.
5-344	Engineer base map depot company.	2	3	129	134	Normally assigned or attached to an engineer base topographic battalion.	Normally 1 per communications zone for bulk map storage and distribution.
5-345	Headquarters and headquarters company, engineer topographic survey group.	24	4	127	155	Zone of interior, theater communications zone.	Commands and supervises attached troops including base topographic battalions.
5-346	Headquarters and headquarters detachment, engineer base topographic battalion.	6	3	49	58	Communications zone or zone of interior.	Provides for the planning and technical control of a flexible base topographic battalion engaged in the compilation, reproduction, and distribution of military maps.

5-347	Engineer base reproduction company.	2	3	118	123	1 each per headquarters and headquarters company, engineer base topographic battalion.	Reproduces maps, charts, and allied mapping materials such as map indexes, trig lists, and gazetteers as required.
5-348	Engineer base survey company.	6	4	155	165	1 or more per headquarters and headquarters company, engineer base topographic battalion as required, or may operate independently.	Performs field surveys and computations relative to new mapping or map revision; performs second and third order geodetic surveys; augments field armies' survey capabilities. Performs surveys for military mapping, artillery, and guided missile needs.
5-349	Engineer base photomapping company.	4	3	177	184	1 each per headquarters and headquarters company, engineer base topographic battalion.	Provides new and revised map manuscripts for reproduction of multi-colored maps; compiles new maps from aerial photography. Prepares controlled mosaics.

Table 2. Engineer Teams

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
	ADMINISTRATIVE AND HEADQUARTERS TEAMS					
AA-----	Platoon headquarters, component of company.	1	0	1	2	Capabilities: Command and administrative control of 2 or more service teams. Basis of Allocation: One per two or more service teams with a strength of not less than 40 individuals. Not required if commissioned officers are assigned to the teams.
AB-----	Platoon headquarters, separate.	1	0	3	4	Capabilities: Command and administrative control of two or more teams not a part of a company. Basis of Allocation: One per unit comprising 40 to 60 individuals. Not required if commissioned officers are assigned to teams.
AC-----	Company headquarters--	2	0	6	8	Capabilities: Command and administrative control of two or more service teams. Basis of Allocation: One per unit comprising 2 or more service platoons with an aggregate strength of not less than 120 individuals.
AD-----	Battalion headquarters---	5	2	15	22	Capabilities: Command and administrative control of 3 or more service companies, or a group of engineer units of company or smaller size with an aggregate strength of approximately 750 to 1,100 individuals; furnishes direct administrative assistance to separate detachments which are not attached to companies. Basis of Allocation: One per group of 3 or more service companies, or teams with an aggregate strength of 750 to 1,100 individuals.
	SUPPLY TEAMS					
BA-----	General supply-----	0	1	23	24	Capabilities: Receives, stores, issues, and maintains records of class II and IV supplies for approximately 35,000 troops.

BB-----	Depot operating-----	1	1	52	54	Basis of Allocation: Normally augments Engineer Depot Company, TOE 5-267, and may augment TOE 5-500, Depot Operating Team BB; one per special task force up to 35,000 troops. Capabilities: Operates a depot for the receipt, storage, and issue of engineer general supplies and equipment, and maintains records of class II and IV supplies for approximately 90,000 troops.
BC-----	Equipment supply-----	0	1	30	31	Basis of Allocation: Normally augments Engineer Depot Company, TOE 5-267, one per special task force from 70,000 to 90,000 troops. Capabilities: Operates a small depot for the receipt, assembly, servicing, issue, and shipment of engineer mechanical and electrical equipment in support of a small task force or base. Capable of equipment supply for a force which includes approximately 35,000 troops; assembly and initial conditioning of heavy engineer equipment for storage or issue to using units; inspection and minor repairs on heavy equipment to depot stock to insure serviceability and maintenance of equipment while in storage.
BD-----	Headquarters, engineer supply control office.	3	1	15	19	Basis of Allocation: Augments Engineer Depot Company, TOE 5-267, and Engineer Depot Battalion, TOE 5-266, and may augment TOE 5-500, Depot Operating Team BB; one per special task force up to 35,000 troops. Capabilities: Provides the administrative personnel to staff a Theater Engineer Supply Control Office. When augmented by Teams BE, BF, BG, and BH, the unit comprises a Theater Engineer Supply Control Office capable of: Forecasting general engineer and repair parts supply requirements of a Theater of Operations to insure maintenance of adequate and realistic stock levels; evaluating stock status reports, tonnage reports, and other special supply reports as required or directed; directing the distribution or relocation of supplies; assembling statistical data pertaining to engineer equipment population and distribution; general engineer and repair parts usage experience, identifying and cataloging locally procured items and other pertinent stock control operations. Basis of Allocation: One per Theater Headquarters.

Table 2. *Engineer Teams*—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
BE-----	General engineer supply control team.	1	1	41	43	Capabilities: Provides the necessary supervisors, analysts, and typists to exercise effective supply control over approximately 10,000 to 11,000 general engineer supply items. Maintains a balanced supply of general engineer items throughout the entire Theater of Operations. Forecasts requirements and resupply of general engineer items for future operations to insure the receipt and ultimate distribution of necessary supplies at the proper time and place. Basis of Allocation: One for control of approximately 10,000 to 11,000 general engineer items.
BF-----	Engineer repair parts supply control team.	1	1	41	43	Capabilities: Provides the necessary supervisors, analysts, and typists to exercise effective supply control over approximately 8,000 to 10,000 rapid turnover repair parts supply line items. Maintains a balanced supply of repair parts items throughout the entire Theater of Operations. Forecasts requirements and resupply of repair parts items for future operations to insure the receipt and ultimate distribution of necessary supplies at the proper time and place. Basis of Allocation: One for control of approximately 8,000 to 10,000 rapid turnover repair parts supply line items.
BG-----	Distribution (stock control) team.	1	1	34	36	Capabilities: Provides the necessary qualified personnel to exercise effective stock control over all general engineer and repair parts items present in or requisitioned for a Theater of Operations. Works in close coordination with the other teams of the Engineer Supply Control Office. Requisitions items from the zone of interior, directs shipments to various storage depots, diverts shipments as necessary, authorizes depot issues, controls ship-

						ments in and out of depots in accordance with regulations, controls the disposal of excess and unserviceable items. Based on data furnished by the Theater Army Engineer, with regard to future operations, prescribes depot missions so as to insure effective and proper distribution of available supplies.
						Basis of Allocation: One or more as required per Theater Engineer Supply Control Office
BH-----	Engineer identification and cataloging team.	3	0	15	18	Capabilities: Identifies and catalogs repair parts and general engineer items of supply which have been locally procured or which through occurrence or omission have lost their identity. Maintains constant liaison with the Theater Procurement Office and local manufacturers to determine facilities and materials available. Prepares the necessary drawings and blueprints required when requesting bids from local manufacturers. Subsequent to inspection and acceptance of an item, the team in coordination with the Team BG arranges for shipment of the item to a storage installation.
						Basis of Allocation: One or more as required per Theater Engineer Supply Control Office.
	MAINTENANCE AND PARTS TEAMS					
EA-----	Field maintenance-----	0	0	10	10	Capabilities: Provides engineer field maintenance support for approximately 140 major items of engineer construction equipment or 90 vehicle equivalents.
						Basis of Allocation: Normally one per special task force requiring a maintenance force of less than a platoon of an engineer field maintenance company or larger maintenance team.
EB-----	Field maintenance-----	0	1	21	22	Capabilities: Provides engineer field maintenance support for approximately 375 major items of engineer construction equipment or 180 vehicle equivalents.
						Basis of Allocation: Normally one per special task force requiring a force of less than a platoon of an engineer field maintenance company or to augment an engineer field maintenance company.

Table 2. *Engineer Teams*—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
EC-----	Special equipment maintenance.	0	0	8	8	Capabilities: Provides technically qualified personnel to operate a mobile machine shop for the repair of special engineer equipment, including sniperscopes, mine detectors, odographs, searchlights, and small quantities of other infrared devices, precision instruments, and similar items. Team is capable of maintaining approximately 1,050 sniperscopes, 700 mine detectors, 25 odographs, 6 searchlights, and miscellaneous items. Basis of Allocation: Normally one per engineer field maintenance company where there is a high concentration of special engineer equipment.
ED-----	Parts-----	0	1	17	18	Capabilities: Provides parts supply support for 1,500 major items of engineer equipment employed by an engineer force operating in an area which does not require support of larger parts supply units. Team can issue approximately 3,000 line items per month, and can store approximately 50 tons of repair parts or 9,000 line items. Basis of Allocation: Normally one per special task force or one per Engineer Field Maintenance Company, TOE 5-157; and as required to support Engineer Parts Depot Company, TOE 5-279, and Engineer Depot Maintenance Company, TOE 5-278.
EE-----	Repair parts instructor-adviser.	0	1	4	5	Capabilities: Provides technically qualified personnel for advising, instructing, and rendering assistance to engineer and engineer equipment using units on repair parts problems such as interpretation of parts supply policies and procedures, procurement, distribution, supply and stock control, storage, utilization, disposition of excesses, and the recovery of reparable parts.

EF-----	Engineer field maintenance (AAA).	0	0	20	20	Basis of Allocation: To engineer supply control offices and similar organizations and Engineer Maintenance and Supply Group, TOE 5-262, as required. Capabilities: Provides qualified personnel and equipment to accomplish field maintenance support of engineer equipment within AAA units. Basis of Allocation: Normally one per AAA Group outside CONUS composed of two to four AAA Missile Battalions NIKE Semimobile TOE 44-145; AAA Battalion 75-mm Gun, Mobile TOE 44-15; AAA Battalion 120-mm Gun, Semimobile TOE 44-115.
EG-----	Engineer field maintenance guided missile (CORPORAL).	0	1	7	8	Capabilities: Provides immediate field maintenance service for the engineer equipment organic to the Ordnance Guided Missile Direct Support Company (CORPORAL) TOE 9-228, and three Field Artillery Missile Battalions, CORPORAL TOE 6-545. Such support will include repairing and/or replacing engines, assemblies of subassemblies, not above field maintenance level, maintaining balanced stocks of repair parts for use of organic maintenance personnel, receive and issue to supported units repair parts for organizational use, assemble and report, through engineer maintenance channels, statistical data on supported engineer equipment, inspecting organizational maintenance activities, technical inspection of engineer equipment, and furnishing of advice on repair parts stock levels for organizational maintenance, and their storage and usage. Basis of Allocation: Normally attached to the Ordnance Guided Missile Direct Support Company (CORPORAL) TOE 9-228.
FIREFIGHTING TEAMS						
FA-----	Firefighting headquarters.	1	0	3	4	Capabilities: Planning for overall strategic fire defense; controls firefighting teams assigned or attached. Basis of Allocation: Normally one per two to four firefighting teams and one water tank team.

Table 2. Engineer Teams—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
FB-----	Fire truck-----	0	0	6	6	Capabilities: Establishes organized fire protection and fire prevention programs in areas to which assigned; will provide fire protection for areas housing 5,000 to 10,000 troops, or warehouse and open stock pile storage of 100,000 square feet. Basis of Allocation: One per post, base, camp, or station housing 5,000 to 10,000 troops, or warehouse and open storage area of 100,000 square feet.
FC-----	Fire trailer-----	0	0	1	1	Capabilities: This team, including team chief with volunteer personnel, will furnish fire protection to an area housing from 5,000 to 10,000 troops, or warehouse and open storage space of 100,000 square feet. Basis of Allocation: One per post, base, camp, or station housing up to 5,000 troops, or warehouse and open storage area of 100,000 square feet when a firetruck team is not required.
FD-----	Water tank-----	0	0	2	2	Capabilities: Transport water for firefighting purposes when insufficient water storage is available. Basis of allocation: One per firefighting platoon; additional as required.
	EQUIPMENT OPERATING TEAMS					
GA-----	Dump truck-----	0	0	13	13	Capabilities: Provides supervisory personnel, drivers, and dump trucks for hauling bulk materials such as dirt, gravel, coal, road metal, etc. Capacity for hauling depends upon factors such as type of material, distance per trip, and loading facilities. Maximum hauling capacity is 40 tons.

GB-----	Rock crusher-----	0	0	4	4	Basis of Allocation: Normally attached to a dump truck company to augment its hauling capacity; may be attached to construction company or service units when required. Capabilities: Provides personnel for the operation of the 50 tons per hour crushing and screening plant. Basis of Allocation: Normally attached to an engineer construction unit to furnish and operate equipment for production of crushed stone necessary for accomplishment of engineer construction missions.
GD-----	Forestry-----	1	0	42	43	Capabilities: Provides personnel and equipment necessary to conduct logging and sawmill operations for the production of rough lumber and timber piling. Capable of producing 10,000 to 15,000 board feet of rough lumber and timber piling per day. Basis of Allocation: Normally attached to an engineer forestry company, but may operate independently when the employment of an engineer forestry company is not warranted.
GE-----	Well drilling-----	0	0	2	2	Capabilities: Provides supervisory personnel and equipment for drilling water wells; installs casings and pumps for wells to supply water to units or stations. Basis of Allocation: Normally attached to a construction unit which will provide additional personnel necessary for well drilling operations.
GF-----	Water purification-----	0	0	4	4	Capabilities: Provides personnel and equipment for purifying up to 3,000 gallons of potable water per hour, and storage facilities for 12,000 gallons. Basis of Allocation: Normally attached to a water supply company, but may operate independently when the employment of a water supply company is not warranted.

Table 2. *Engineer Teams*—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
GG-----	Water purification-----	1	0	11	12	Capabilities: Provides supervisory personnel for the operation of a central water plant or a municipal water system. Operates single or multiple standard purification units forming a central plant supporting 6,000 to 60,000 individuals when augmented by utilities personnel. Operates central municipal water system supporting up to 200,000 personnel when augmented by utilities personnel, civilian, and/or prisoner of war operating personnel. Basis of Allocation: Normally one per engineer brigade.
GH-----	Water transport-----	0	0	8	8	Capabilities: Provides personnel and equipment for short hauls or from approximately 10 to 15 miles to transport water in bulk to dry water points; 4,500 gallons may be transported at one trip. Daily capacity depends on such factors as (1) length of haul, (2) condition of roads, and (3) situation if in a zone subject to enemy attack. Basis of Allocation: Normally one per water supply company.
GI-----	Gas generating-----	1	0	25	26	Capabilities: Provides necessary technically qualified personnel to operate one acetylene generating plant of 750 cubic feet per hour capacity, and two oxygen and nitrogen generating plants of 1,000 cubic feet per hour capacity each. Unit operates and maintains machinery to generate acetylene, oxygen, and nitrogen gases, and to store limited quantities of these gases. Basis of Allocation: Normally one attached to the engineer maintenance and supply group.

GJ-----	Carbon dioxide generating.	1	0	12	13	Capabilities: Provides necessary technically qualified personnel for the generating, storage, and transportation of carbon dioxide in gaseous and liquid form and in the form of dry ice. Unit operates machinery for the generation of hydrogen and carbon dioxide gases, and to store limited quantities of these gases. Basis of Allocation: Normally one attached to the engineer maintenance and supply group.
GK-----	Quarrying and processing (Tentative).	1	0	36	37	Capabilities: Provides personnel and equipment for the operation of the 225 tons per hour crushing, screening, and washing plant. Provides necessary personnel and equipment for drilling and blasting operations required to produce raw stone for crushing. Basis of Allocation: To Engineer Heavy Construction Battalion, TOE 5-355, as required.
CONSTRUCTION, UTILITIES, AND ELECTRICAL POWER TEAMS						
HA-----	Port construction headquarters.	2	0	2	4	Capabilities: Provides technically qualified personnel to augment an engineer staff section or unit for the performance of specialized phases of port planning, such as capacity, layout, site selection, design, material requirements, and special equipment needs. Basis of Allocation: Normally one per engineer group when engaged in major port projects.
HB-----	Diving-----	1	0	9	10	Capabilities: Provides personnel and equipment to perform marine diving in support of port construction and rehabilitation and other types of engineer construction, including underwater pipelines which may require diving personnel and equipment. Basis of Allocation: Normally one per engineer group when engaged in major port or underwater pipeline projects.
HC-----	Welding-----	0	0	4	4	Capabilities: Provides technically qualified welders and equipment for attachment to units where the organic personnel and equipment are inadequate. Basis of Allocation: Normally one per engineer construction group and two per engineer maintenance and supply group.

Table 2. *Engineer Teams*—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
HD-----	Utilities-----	1	0	27	28	Capabilities: Provides personnel and equipment for maintenance of utilities at installations up to 2,500 individuals; provides post engineer service to overseas or theater of operations installations; maintains utilities and furnishes utilities service and repair, including refrigeration maintenance. Basis of Allocation: Normally one per overseas camp, base, depot, or installations up to 2,500 individuals.
HE-----	Utilities-----	1	1	44	46	Capabilities: Provides personnel and equipment for maintenance of utilities at installations up to 4,000 individuals; provides post engineer service in overseas or theater of operations installations; maintains utilities and furnishes utilities service and repair, including refrigeration maintenance. Basis of Allocation: Normally one per overseas camp, base, depot, or installations up to 4,000 individuals.
HF-----	Utilities-----	2	1	52	55	Capabilities: Provides personnel and equipment for maintenance of utilities at camps, bases, and depots for installations up to 6,000 individuals; provides post engineer service in overseas or theater of operations installations; maintains utilities and furnishes utilities service and repair, including refrigeration maintenance. Basis of Allocation: Normally three in communications zone area per supported field army.
HG-----	Utilities-----	3	1	79	83	Capabilities: Provides personnel and equipment for maintenance of utilities at camps, bases, and depots for installations up to 10,000 individuals; provides post engineer service in overseas or theater of operations installations; maintains utilities and furnishes utilities service and repair, including refrigeration maintenance.

HH-----	Power line-----	1	0	12	13	Basis of Allocation: Normally one per typical field army and two in communications zone area per supported field army. Capabilities: Provides technically qualified personnel and tools for the installation of high voltage electric power lines, and the maintenance of approximately 60 miles of high voltage electric power lines. Basis of Allocation: Normally one per two electric power generating plants of 300 to 2,500 kw. capacity.
HI-----	Powerplant maintenance	0	1	12	13	Capabilities: Provides technically qualified personnel and equipment for maintenance of electric power generating plants of 300 to 2,500 kw. capacity, when welding team HC is attached, and furnishes supervisory personnel for construction and rehabilitation of such plants. Basis of Allocation: Normally one per two electric power generating plants of 300 to 2,500 kw. capacity.
HJ-----	Powerplant operating----	1	0	10	11	Capabilities: Provides technically qualified personnel for the operation of electrical powerplants containing from one to three diesel engine driven generators, capacities of which range from 300 to 2,500 kw. Basis of Allocation: Normally four per engineer brigade in communications zone area.
HK-----	Foundry-----	1	0	12	13	Capabilities: Provides technically qualified personnel for the operation of one set of engineer foundry equipment. Basis of Allocation: Normally one per engineer depot maintenance company when foundry service is required.

Table 2. *Engineer Teams*—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
HL-----	Engineer floating power-plant.	5	1	60	66	Capabilities: When augmented by one mess team CA and two mess teams CB from TOE 29-500, this unit is capable of 24-hour operation for extended periods at full rated load; providing continuous 3-phase, 60-cycle, electric power in quantities up to 34,500 kw. at output voltages between 13,800 and 115,000 volts; supplying electric power to civilian or military installations near shore, harbor, or navigable stream at proper voltages by means of variable step-up transformers; supplying electric power to shore and inland areas by means of connection to existing transmission lines. Capable of routine and emergency maintenance and minor repairs of equipment by assigned personnel. Towing vessel is required to move this ship.
HL-----	Engineer floating power-plant.	5	1	60	66	Basis of Allocation: As required in theater of operations, communications zone, and zone of interior.
HM-----	Railway mounted power-plant.	2	0	14	16	Capabilities: Provides electric power for direct support of our Armed Forces and to meet any critical electrical requirements of civilians in occupied countries; to provide sufficient electrical power for military installations, industrial plants, or limited population centers at proper voltages through variable step-up transformers; to meet varying foreign and domestic situations of either 50- or 60-cycle current under a wide variety of output voltages; supply electrical power to areas by means of connection to existing transmission lines; capable of 24-hour operation for extended periods at full rated load with powerplant operations to be carried on by assigned personnel; capable of routine and emergency maintenance and minor repairs of equipment by assigned personnel. Unit is not self-propelled and a towing engine must be furnished. Basis of Allocation: As required in theater of operations and zone of interior.

HN-----	Engineer Camouflage (Heavy Weapons).	1	0	36	37	Capabilities: Provides personnel and equipment for the employment of the Decoy Target Gun 280-mm. w/Carriage Medium Fidelity Pneu w/Carrying Case in a theater of operation. Basis of Allocation: Normally one per 280 mm. Gun, Field Artillery Battalion in the theater of operations. As required when other deception operations are contemplated.
TOPOGRAPHIC AND INTELLIGENCE TEAMS						
IA-----	Survey-----	0	0	14	14	Capabilities: Provides technically qualified personnel and equipment for the survey operations of one party. Basis of Allocation: Normally one per engineer brigade.
IB-----	Survey platoon-----	1	0	39	40	Capabilities: Provides technically qualified personnel and equipment for three survey parties, and limited preparation of map manuscript. Basis of Allocation: Normally attached to Engineer Base Survey Company, TOE 5-348, when mapping operations require additional effort but less than a base survey company.
IC-----	Photomapping platoon---	1	1	77	79	Capabilities: Provides technically qualified personnel and equipment for the preparation of topographic maps by multiplex methods from aerial photographs. Basis of Allocation: Normally attached to Engineer Base Photomapping Company, TOE 5-349, when mapping operations require additional effort but less than a base photomapping company.
ID-----	Map reproduction platoon.	1	1	51	53	Capabilities: Provides technically qualified personnel and equipment for the production of maps from original manuscripts, and limited quantities of photostats. Basis of Allocation: Normally attached to Engineer Base Map Reproduction Company, TOE 5-347, when mapping operations require additional effort but less than a base map reproduction company.

Table 2. *Engineer Teams*—Continued

Designation	Name	Authorized strength			Capabilities and basis of allocation
		Off	WO	EM	Total
IE-----	Map depot platoon-----	1	0	38	39
Capabilities: Provides technically qualified personnel and equipment for the receipt, storage, issue, and distribution of maps of a base, army, or corps headquarters. Platoons can operate as a depot. Basis of Allocation: Normally three per army topographic battalion for forward depots.					
IF-----	Relief-map making-----	0	1	17	18
Capabilities: Provides technically qualified personnel and equipment to construct original terrain models at scales from 1:5,000 through 1:50,000, and produce quantities of plastic reproduction at these scales. Basis of Allocation: Normally one per base topographic battalion.					
IG-----	Technical intelligence collection.	3	0	6	9
Capabilities: Provides technically qualified personnel and equipment for finding, collecting, identifying, photographing, and reporting on elements of engineer technical intelligence, such as: foreign engineer materiel (equipment), construction, organization, training, tactics, techniques, installations, and fortifications; also illustrating and preparing training aids and instruction in the use of, or counter-acting enemy engineer material. Basis of Allocation: Normally one per corps.					
IH-----	Technical intelligence, research.	5	0	8	13
Capabilities: Provides technically qualified personnel and equipment for collecting, receiving, evaluating, photographing, and reporting on elements of engineer technical intelligence, such as: engineer materiel, construction, organization, training, tactics, techniques, installation fortifications, and research and development, illustrating and preparing training aids of items of engineer intelligence. Assists with the interrogation of enemy military and civilian personnel for engineer intelligence, and coordinates the activities of engineer technical intelligence teams IG (Collection). Basis of Allocation: Normally one per field army.					

IJ-----	Geodetic survey-----	4	1	7	12	Capabilities: Provides technically qualified personnel for instruction and/or supervision of units engaged in high-order geodetic surveys and computations as required in a theater of operations survey program and as otherwise required in the field army for guided missile support. Basis of Allocation: One per theater of operations and normally one per field army when required.
IK-----	Terrain-----	6	0	5	11	Capabilities: Provides technically qualified personnel and equipment for the collection, evaluation, and dissemination of terrain data; the production of terrain studies; and provision of consultant services in military geology and military hydrology. Basis of Allocation: Normally one per army but may be assigned at a lower level.
IL-----	Topographic liaison-----	7	1	9	17	Capabilities: a. Map program planning and technical supervision of map compilation; surveying and geodetic activities including supervision, collection, maintenance and dissemination of survey control data; supervision and coordination of map reproduction including evaluation of reproduction facilities and planning the employment of such facilities in the map reproduction program; supervision of the topographic and map supply program; including operation of map depots and supply points throughout the command. Maintains liaison with higher headquarters and allied armies. Supervise non-United States indigenous reproduction and mapping agencies used in the program. b. Transportation will be provided by area motor pools, or organization to which attached. Basis of Allocation: One per theater, army group, field army headquarters, or base topographic battalion as required.
IM-----	Photographic evaluation-----	0	1	8	9	Capabilities: Provides technically qualified personnel and equipment for assisting photographic units in accomplishing aerial cartographic photography suitable for the compilation of military topographic maps, also the evaluation of such photography to determine its suitability for the required purpose.

Table 2. Engineer Teams—Continued

Designation	Name	Authorized strength				Capabilities and basis of allocation
		Off	WO	EM	Total	
	DREDGE CREWS					Basis of Allocation: As required, normally attached to Headquarters and Headquarters Detachment, Engineer Base Topographic Battalion, TOE 5-346.
JA-----	20-inch-cutter pipeline dredge.	4	6	48	58	Capabilities: When augmented by labor personnel from TOE 10-67 or other available labor sources and a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personnel for the operation and maintenance of the engineer dredge, non-self-propelled, diesel powered, 20-inch-cutterhead type, pipeline.
JB-----	24-inch-cutter pipeline dredge.	3	6	38	47	Basis of Allocation: As required. Capabilities: When augmented by labor personnel from TOE 10-67 or other available labor sources, and a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personnel for the operation and maintenance of the engineer dredge, turbine powered, 24-inch-cutterhead type, non-self-propelled, pipeline.
JC-----	700-cubic-yard diesel-electric seagoing hopper dredge.	5	4	39	48	Basis of Allocation: As required. Capabilities: When augmented by a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personnel for the operation and maintenance of the engineer dredge, seagoing hopper, diesel electric powered, 700 cubic yard. Basis of Allocation: As required.

JD-----	1,400-cubic-yard diesel-electric seagoing hopper dredge.	8	4	40	52	Capabilities: When augmented by a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personnel for the operation and maintenance of the engineer dredge, seagoing hopper, diesel electric powered, 1,400 cubic yard. Basis of Allocation: As required.
JE-----	2,700-cubic-yard diesel-electric seagoing hopper dredge.	8	4	44	56	Capabilities: When augmented by a minimum of one mess team CA and one mess team CB from TOE 29-500, this unit provides personnel for the operation and maintenance of the engineer dredge, seagoing hopper, diesel electric powered, 2,700 cubic yard. Basis of Allocation: As required.

CHAPTER 3

LOGISTICAL DATA

Section I. EQUIPMENT OTHER THAN MOTORIZED

6. Engineer Equipment

Table 3 gives the nomenclature, dimensions, cubages, and weights of sets of engineer equipment and engineer equipment chests.

Table 3. Sets of Engineer Equipment

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
1080-S01-----	CAMOUFLAGE TRAINING SET: Aviation Engineer-----	-----	-----	-----	879.0	15,150.0
1080-S02-----	CAMOUFLAGE TRAINING SET: Company-----	-----	-----	-----	326.9	7,150.0
1080-S03-----	CAMOUFLAGE TRAINING SET: General Purpose-----	-----	-----	-----	284.6	3,000.0
1080-S04-----	CAMOUFLAGE TRAINING SET: Maintenance-----	-----	-----	-----	102.0	1,597.0
1080-S05-----	CAMOUFLAGE NET SET: Single Engine Aircraft-----	-----	-----	-----	80.0	1,271.0
1080-S06-----	CAMOUFLAGE NET SET: Antiaircraft Machinegun, 50 Caliber.	-----	-----	-----	6.0	145.0
1080-S07-----	REPAIR EQUIPMENT: Pneumatic Target, Set No. 8-----	-----	-----	-----	6.6	180.0
1080-S08-----	CAMOUFLAGE NET SET: Field Artillery, Drape Type-----	-----	-----	-----	179.0	1,904.0
1080-S09-----	CAMOUFLAGE NET SET: Field Artillery, Drape Type, 75-mm. Gun, 105- and 155-mm. Howitzers and Ser 784.	-----	-----	-----	65.0	997.0
1080-S10-----	CAMOUFLAGE NET SET: Antiaircraft Gun, Drape Type, 40-mm. Gun.	-----	-----	-----	362.0	573.0
1080-S11-----	CAMOUFLAGE NET SET: Antiaircraft Machine Gun, Drape Type, 50-Caliber Gun.	-----	-----	-----	32.5	527.0
1080-S12-----	CAMOUFLAGE NET SET: Antiaircraft Gun, M2, U/W 105- and 155-mm. Gun.	-----	-----	-----	44.0	930.0
1080-S13-----	CAMOUFLAGE NET SET: Antiaircraft Gun, M2, U/W 40-mm. Gun.	-----	-----	-----	17.0	412.0
1080-S14-----	CAMOUFLAGE NET SET: Antiaircraft Gun M2, U/W 90-mm. Gun.	-----	-----	-----	17.0	412.0
1080-S15-----	CAMOUFLAGE NET SET: Field Artillery-----	-----	-----	-----	43.5	968.0
1080-S16-----	CAMOUFLAGE NET SET: Twin Engine Fighter Aircraft-----	-----	-----	-----	95.0	2,000.0
1080-S17-----	CAMOUFLAGE NET SET: Antiaircraft Gun, U/W 120-mm. Gun.	-----	-----	-----	38.2	1,411.0
1080-S18-----	COVER, SHADE: Bomber Aircraft-----	-----	-----	-----	200.0	4,800.0
1080-S19-----	COVER, SHADE: Fighter Aircraft-----	-----	-----	-----	50.0	1,150.0

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
1095-S01	MINE PLANTING EQUIPMENT: Mechanical				6, 125. 0	61, 200. 0
2090-S02	CONSTRUCTION OUTFIT: Raft, Infantry Support				813. 0	9, 912. 0
2090-S04	REPAIR EQUIPMENT: Plywood Boat and Ponton				6. 1	218. 0
2090-S05	REPAIR KIT: Inflatable Craft				77. 0	1, 200. 0
2909-S06	REPAIR KIT: Aluminum Craft				14. 6	23. 6
2090-S07	REPAIR EQUIPMENT: Plastic Assault Boat				2. 0	110. 0
3220-S01	SHOP EQUIPMENT, WOODWORKING, Base Maintenance.				250. 0	4, 800. 0
3220-S02	SHOP EQUIPMENT, WOODWORKING, Base Maintenance, Trailer Mounted.				699. 0	6, 100. 0
3424-S01	SHOP EQUIPMENT: Forge, Base Maintenance				1, 967. 0	36, 215. 0
3428-S01	SHOP EQUIPMENT: Base Maintenance, Foundry				3, 650. 0	108, 400. 0
3449-S01	SHEET METALWORKING SET: Machine, Set 2				350. 0	74, 000. 0
3470-S02	SHOP EQUIPMENT: Machine, Shop, Base Maintenance				3, 590. 0	75, 000. 0
3540-S01	PRESERVATION AND PACKAGING EQUIPMENT SET: Unmounted.				576. 0	17, 500. 0
3540-S01	PRESERVATION AND PACKAGING EQUIPMENT SET: Mounted on 6-ton Semitrailer.				2, 395. 0	28, 000. 0
3610-S01	REPRODUCTION SET: Ammonia Process				75. 0	790. 0
3610-S02	REPRODUCTION SET: Black and White Process				10. 0	230. 0
3610-S05	REPRODUCTION SET: Spirit Process, 22½ by 29 in				93. 9	800. 0
3610-S06	REPRODUCTION SET: Ammonia Process, Continuous Tone.				220. 0	3, 800. 0
3610-S07	REPRODUCTION SET: Topographic, Photolithographic				2, 130. 0	23, 233. 0
3610-S13	REPRODUCTION SET: Silk Screen Process				19. 0	619. 0

3610-S14.....	PHOTOGRAPHIC PRINTING AND PROCESSING SECTION: Topographic Reproduction Set, 190-in. Wheelbase.	324.0	96.5	132.0	2,388.4	21,030.0
3610-S16.....	PLATE GRAINER SECTION, TOPOGRAPHIC REPRODUCTION SET: Truck Mounted.	107.0	72.0	77.0	344.0	11,790.0
3610-S17.....	PRESS SECTION, TOPOGRAPHIC REPRODUCTION SET: Truck Mounted.	324.0	96.5	132.0	2,388.4	23,200.0
3610-S18.....	LABORATORY SECTION: Topographic Reproduction Set, Truck Mounted.	324.0	96.5	132.0	2,388.4	18,550.0
3610-S19.....	MAP LAYOUT SECTIONS: Topographic Reproduction Set, Truck Mounted.	324.0	96.5	132.0	2,388.4	18,090.0
3610-S20.....	PLATE PROCESS SECTION: Topographic Reproduction Set, Truck Mounted.	324.0	96.5	132.0	2,388.4	18,950.0
3610-S22.....	CAMERA SECTION: Topographic Reproduction Set, Truck Mounted.	333.0	96.0	132.0	2,442.0	17,520.0
3655-S03.....	GENERATING AND CHARGING PLANT: Hydrogen Carbon Dioxide, Semitrailer Mounted.	-----	-----	-----	17,400.0	732,800.0
3695-S01.....	LOGGING EQUIPMENT SET: Truck Mounted	-----	-----	-----	2,761.8	26,645.0
3820-S01.....	PNEUMATIC TOOL AND COMPRESSOR OUTFIT: Trailer Mounted, 55 c.f.m.	-----	-----	-----	82.0	1,800.0
3820-S02.....	PNEUMATIC TOOL AND COMPRESSOR OUTFIT: Truck Mounted, 210 c.f.m.	-----	-----	-----	1,227.0	17,300.0
3820-S03.....	EXPLORATORY CORE SET: Airborne	-----	-----	-----	75.0	550.0
3820-S04.....	PAVING BREAKER SET, PORTABLE: For Breaking Concrete.	-----	-----	-----	17.9	550.0
3820-S05.....	CRUSHING, SCREENING AND WASHING PLANT: 150 tons per hr.	-----	-----	-----	9,167.0	100,000.0
3820-S06.....	DRILL SHARPENING EQUIPMENT	-----	-----	-----	540.0	13,300.0
3820-S07.....	ROCK DRILLING EQUIPMENT: 50 tons per hr.	-----	-----	-----	575.0	15,600.0
3820-S08.....	AUGERING SET: Earth, Airborne	-----	-----	-----	60.0	400.0
3820-S09.....	CRUSHING, SCREENING AND WASHING PLANT: Diesel and Electric Driven, 225 tons per hr.	-----	-----	-----	35,000.0	415,000.0

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
3820-S10-----	CRUSHING, SCREENING AND WASHING PLANT: Gasoline and Electric Driven, 225 tons per hr.	-----	-----	-----	36,000.0	420,000.0
3830-S01-----	MAGNET, SWEEPER, ROAD-----	-----	-----	-----	160.0	6,500.0
3835-S10-----	PIPELINE EQUIPMENT SET: For 2½-ton truck-----	-----	-----	-----	462.0	4,266.0
3835-S25-----	PIPELINE CONSTRUCTION EQUIPMENT: Truck Mounted.	-----	-----	-----	1,120.0	16,240.0
3895-S01-----	ASPHALT, MIXING AND PAVING SET: 80 tons per hr.--	-----	-----	-----	22,100.0	350,000.0
3895-S02-----	JETTING SET: Portable-----	-----	-----	-----	185.0	4,200.0
4210-S01-----	FIRE FIGHTING EQUIPMENT SET-----	-----	-----	-----	153.0	5,398.0
4210-S02-----	FIRE FIGHTING EQUIPMENT SET-----	-----	-----	-----	173.3	3,340.0
4210-S03-----	FIRE FIGHTING EQUIPMENT SET: Set 3 Pumper 400 g.p.m., W/Trailer, Overseas.	-----	-----	-----	557.0	9,123.0
4210-S04-----	REPAIR AND REFILLING KIT: Carbon Dioxide Fire Extinguisher.	-----	-----	-----	3.0	80.0
4210-S05-----	FIRE FIGHTING EQUIPMENT SET: Truck Mounted, Zone of Interior.	-----	-----	-----	1,237.3	13,232.0
4210-S09-----	FIRE FIGHTING EQUIPMENT SET: Set 18, W/Truck, Overseas.	-----	-----	-----	1,880.0	22,700.0
4210-S11-----	FIRE FIGHTING EQUIPMENT SET: W/Truck, Guided Missile.	-----	-----	-----	9.0	29.0
4210-S12-----	FIRE FIGHTING EQUIPMENT SET: W/Trailer, Guided Missile.	-----	-----	-----	960.0	7,700.0
4210-S13-----	FIRE FIGHTING EQUIPMENT SET: W/Truck and Trailer Redstone Missile.	-----	-----	-----	N/A	60,000.0
4210-S14-----	FIRE FIGHTING EQUIPMENT SET: Set 21, W/Truck, Army Aircraft Crash.	-----	-----	-----	1,760.0	21,000.0

4210-S15-----	FORCED ENTRY AND RESCUE EQUIPMENT SET: Aircraft Crash.	-----	-----	-----	47.0	340.0
4220-S01-----	DIVING EQUIPMENT SET: 2 Persons, 200-foot Depth	-----	-----	-----	234.0	8,219.0
4220-S02-----	DIVING EQUIPMENT SET: 2 Persons, 100-foot Depth	-----	-----	-----	29.0	711.0
4220-S04-----	DIVING EQUIPMENT SET: Laru, 1 Person, 30-foot Depth.	-----	-----	-----	4.5	130.0
4320-S01-----	PUMP ASSEMBLY: Rotary, Power Driven, ENG Well Development and Production Set 1.	-----	-----	-----	790.0	24,882.0
4320-S02-----	PUMP ASSEMBLY: Rotary, Power Driven, ENG Well Development and Production Set 2.	-----	-----	-----	613.9	16,515.0
4610-S01-----	WATER PLANT: EQUIPMENT SET: 900 gal. per hr.	-----	-----	-----	254.0	4,136.0
4610-S02-----	WATER PURIFICATION EQUIPMENT SET: 2,100 gal. per hr.	-----	-----	-----	262.0	5,158.0
4610-S03-----	WATER PURIFICATION EQUIPMENT SET: Diato- mite Filter, 3,000 gal. per hr. Set 4.	-----	-----	-----	695.0	9,610.0
4610-S06-----	FILTER UNIT: Water Purification, Knapsack Type, ¼ g.p.m. Hand Driven.	-----	-----	-----	4.5	62.0
4620-S02-----	DISTILLATION EQUIPMENT SET: Water, Trailer Mounted, 60 gal. per hr.	-----	-----	-----	665.2	6,775.0
4620-S06-----	DISTILLATION EQUIPMENT SET: Water, Skid Mounted, 150 gal. per hr.	-----	-----	-----	380.0	8,900.0
4940-S03-----	SHOP EQUIPMENT: Base Maintenance, Electrical Repair	-----	-----	-----	224.0	5,720.0
4940-S06-----	SUPPLEMENTARY EQUIPMENT: Heavy Shop Com- pany.	-----	-----	-----	545.0	47,100.0
4940-S07-----	SUPPLEMENTARY EQUIPMENT: Maintenance Com- pany.	-----	-----	-----	523.2	17,650.0
4940-S08-----	GENERAL PURPOSE REPAIR SHOP EQUIPMENT: Base Maintenance.	-----	-----	-----	1,659.0	29,602.0
4940-S09-----	TOOLROOM EQUIPMENT: Heavy, Base Maintenance	-----	-----	-----	192.0	7,422.0
4940-S11-----	SHOP EQUIPMENT: General Purpose Repair, Semi- trailer Mounted.	-----	-----	-----	1,910.0	22,700.0

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
4940-S12	SHOP EQUIPMENT: Organizational Repair, Light, Truck Mounted.				2, 230. 0	22, 120. 0
4940-S13	SHOP EQUIPMENT: Contact Maintenance, Truck Mounted.				906. 0	8, 980. 0
4940-S14	SHOP EQUIPMENT: Electrical Repair, Semitrailer Mounted.				2, 296. 8	20, 600. 0
5180-S01	ERECTION OUTFIT: High Bolted Storage Tanks				96. 0	2, 700. 0
5180-S02	TOOL KIT: Supplemental, Pipeline Pump Station				2. 0	80. 0
5180-S03	ERECTION OUTFIT: Low Bolted Storage Tanks				1. 5	70. 0
5180-S04	TOOL KIT: Carpenter's Engineer Squad				17. 0	330. 0
5180-S05	TOOL KIT: Carpenter's Engineer Platoon				8. 0	230. 0
5180-S06	TOOL KIT: Carpenter's Set 3, Engineer Combat Platoon, w/case.				5. 0	132. 0
5180-S08	TOOL KIT: Sheet Metal Worker's				7. 0	176. 0
5180-S09	TOOL AND EQUIPMENT KIT: Pioneer, M-4 Floating Bridge, Set 5.				34. 0	1, 245. 0
5180-S11	INTRENCHING OUTFIT: Infantry				250. 0	4, 650. 0
5180-S13	PNEUMATIC TOOL OUTFIT: Set 1				128. 3	3, 040. 0
5180-S15	TOOL KIT: Pioneer, Engineer Combat Platoon				12. 0	325. 0
5180-S16	TOOL KIT: Pioneer, Engineer Platoon, Set 2				221. 0	2, 075. 0
5180-S17	TOOL KIT: Pioneer, Engineer Squad				26. 0	752. 0
5180-S18	TOOL KIT: Pioneer, General Utility				N/A	N/A
5180-S19	TOOL KIT: Mason and Concrete Finisher's				7. 6	103. 0
5180-S20	TOOL KIT: Tractor, Base Maintenance, Set 8				4. 7	351. 0
5180-S22	TOOL KIT: Blacksmith's, General				29. 0	1, 160. 0
5180-S23	TOOL KIT: Diesel Injector Repair, Set 9				2. 6	62. 0
5180-S24	TOOL KIT: Rigging, Wire Rope				3. 5	167. 0

5180-S25	TOOL KIT: Pioneer Cavalry			6.0	175.0
5180-S26	TOOL KIT: Light Machine Repair			6.3	200.0
5180-S27	TOOL KIT: Precision Instrument Repairs			11.0	308.0
5180-S28	TOOL KIT: Service Refrigerator Unit, Set 7			7.8	317.0
5180-S30	TOOL/EQUIPMENT KIT: Supplementary, Water Supply Company.			57.0	780.0
5180-S31	TOOL KIT: Outboard Motor Repair, Set 5			1.4	44.0
5180-S32	TOOL KIT: Tractor, Field Maintenance, Set 7			3.5	216.0
5180-S33	TOOL KIT: Pipe Fitter's, Set 1			7.0	200.0
5180-S34	TOOL KIT: Pipefitter's, Set 2			9.0	45.0
5180-S36	TOOL OUTFIT: Pioneer, Portable Electric Tools			248.0	1,950.0
5180-S38	TOOL KIT: Pipeline Construction, Grooved Coupling			28.0	900.0
5180-S39	TOOL KIT: Pipeline Cutting, Grooving and Beveling			160.0	4,500.0
5420-S02	BRIDGE ERECTION SET: Fixed Bridge, Steel, Railway			650.0	18,400.0
5420-S04	BRIDGE: Floating, Aluminum, Highway Type, M-4			49,880.0	576,000.0
5420-S05	BRIDGE: Floating, Highway, Class 60			41,000.0	834,000.0
5420-S06	BRIDGE: Floating, Steel Treadway Widened			11,320.0	299,000.0
5420-S07	CABLEWAY SET: Aerial, 3,000 lb.			1,200.0	20,000.0
5420-S08	FERRY CONVERSION SET: Raft			26.0	468.0
5420-S09	BRIDGE ERECTION SET: Suspension Bridge, for Foot-bridge and Light Equipment Bridge.			N/A	N/A
5420-S10	BRIDGE SUSPENSION: Foot 2,000 lb. capacity			130.0	5,260.0
5420-S11	BRIDGE SUSPENSION: Light Equipment, 4,000 lb. capacity.			62.0	3,850.0
5420-S12	TRAMWAY SET: Aerial, Light M-2			2,369.0	51,290.0
5420-S13	TRAMWAY EXTENSION SET: Aerial, 1,000 feet			588.0	10,000.0
5420-S14	CASUALTY EVACUATION SET: Cable, Gravity, 200 lb. capacity.			16.0	710.0
5420-S15	BRIDGE ERECTION SET: Floating Bridge			175.0	4,775.0
5420-S16	BRIDGE, FIXED: Steel, Highway, 30 ft. lg. of Span, Semipermanent.			302.0	12,920.0

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
5420-S17-----	BRIDGE, FIXED: Steel, Highway, 60 ft. lg. of Span, Semipermanent.	-----	-----	-----	892. 0	45, 800. 0
5420-S18-----	BRIDGE, FIXED: Highway, 90 ft. lg. of Span, Semi- permanent.	-----	-----	-----	1, 944. 0	61, 600. 0
5420-S20-----	BRIDGE, FIXED: Steel, Railway, 17 ft. lg. of Span-----	-----	-----	-----	66. 6	5, 104. 0
5420-S21-----	BRIDGE, FIXED: Steel, Railway Type, 21 ft. lg. of Span I-Beam.	-----	-----	-----	160. 0	8, 655. 0
5420-S22-----	BRIDGE, FIXED: Railway, 27 ft. lg. of Span-----	-----	-----	-----	205. 2	11, 518. 0
5420-S23-----	BRIDGE, FIXED: Railway, 31 ft. lg. of Span-----	-----	-----	-----	339. 8	18, 568. 0
5420-S24-----	BRIDGE, FIXED: Railway, 35 ft. lg. of Span-----	-----	-----	-----	382. 2	20, 835. 0
5420-S25-----	GIRDER SPLICING SET: Fixed Bridge, I-Beam, 25 in-----	-----	-----	-----	1. 6	202. 0
5420-S26-----	GIRDER SPLICING SET: Fixed Bridge, I-Beam, 19 in-----	-----	-----	-----	1. 5	150. 0
5420-S27-----	BRIDGE, FIXED: Railway Type, 123 ft. lg. of Span, Through Truss.	-----	-----	-----	5, 240. 0	273, 324. 0
5420-S28-----	BRIDGE CONVERSION SET: Fixed Bridge, Steel, Rail- way, Set A.	-----	-----	-----	20. 0	3, 360. 0
5420-S29-----	BRIDGE CONVERSION SET: Fixed Bridge, Through Truss	-----	-----	-----	53. 6	3, 549. 0
5420-S30-----	BRIDGE CONVERSION SET: Fixed Bridge-----	-----	-----	-----	5. 5	353. 0
5420-S31-----	BRIDGE CONVERSION SET: Fixed Bridge, Through Truss.	-----	-----	-----	8. 0	531. 0
5420-S32-----	BRIDGE CONVERSION SET: Fixed Bridge, Through Truss.	-----	-----	-----	1, 271. 0	69, 679. 0
5420-S33-----	BRIDGE, FIXED: Railway, 70 ft. lg-----	-----	-----	-----	1, 797. 0	145, 338. 0
5420-S34-----	BRIDGE, FIXED: 70 ft. lg. of Span, Through-----	-----	-----	-----	1, 320. 6	97, 361. 0
5420-S35-----	BRIDGE CONVERSION SET: Fixed Bridge, Unit Con- struction.	-----	-----	-----	24. 8	3, 773. 0

5420-S36	BRIDGE CONVERSION SET: Fixed Bridge, Unit Construction.				63.6	10,294.0
5420-S37	BRIDGE CONVERSION SET: Fixed Bridge, Unit Construction.				8.0	450.0
5420-S38	BRIDGE CONVERSION SET: Fixed Bridge, Unit Construction.				108.0	6,270.0
5420-S39	BRIDGE, FLOATING: Aluminum, Foot				1,319.0	19,318.0
5420-S43	BRIDGE CONVERSION SET: Fixed Bridge, Bailey Panel Crib Pier.	122.0	60.0	38.0	161.0	11,670.0
5420-S44	BRIDGE ERECTION SET, FLOATING BRIDGE: Class 60 with Steel Superstructure.				185.0	7,125.0
5420-S45	REPAIR EQUIPMENT: Aluminum Floating Bridge, for M4 Bridge, Floating.				103.0	3,413.0
5420-S46	TRAMWAY SET: Aerial, Light, Pioneer Tramway and Cableway.				595.0	16,000.0
5420-S47	TRESTLE, RAILWAY: Steel, L-Type				N/A	N/A
5420-S48	TRESTLE, RAILWAY: T-Type				N/A	N/A
5420-S49	BRIDGE, FLOATING: Aluminum, Highway, Deck Balk Superstructure.				249.1	20,080.0
5420-S51	BRIDGE, FIXED: Steel Highway Type				6,251.0	170,222.0
5420-S52	TRAINING SET: Floating Bridge				53,000.0	290,000.0
5420-S53	BRIDGE, FIXED: Aluminum, Single Lane, Highway, Pony Truss.				15,800.0	169,000.0
5420-S54	BRIDGE, ERECTION SET: Fixed Bridge Aluminum, Single Lane, Highway, Pony Truss.				2,110.0	33,500.0
5420-S55	BRIDGE, FIXED: Highway, Pony Truss, Bailey Type					
5420-S56	BRIDGE ERECTION SET: Highway, Pony Truss, Bailey Type.				¹ 7,000.0	¹ 250,500.0
5420-S57	BRIDGE, FIXED: Aluminum, Highway Type, 38 ft. lg. of Span.				1,050.0	21,500.0

¹Total.

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
5420-S65	BRIDGE, FLOATING: Raft Section, Light Tactical				1,600.0	17,250.0
5430-S01	TANK ASSEMBLY: Fabric, Collapsible, 10,000 gal. capacity, for Petroleum.				88.0	1,455.0
5450-S01	TOWER ERECTION SET: Topographic, W/Tower				426.0	8,360.0
5850-S01	SNIPERSCOPE, INFRARED: Set 1				5.3	165.0
5850-S02	EQUIPMENT REPAIR SET: Sniper Scope Set 13				.1	3.0
6210-S01	SUPPLEMENTARY EQUIPMENT AIRCRAFT OPER- ATIONAL AREA LIGHT SET: Heliport, Portable.				14.0	500.0
6210-S02	SUPPLEMENTARY EQUIPMENT AIRCRAFT OPER- ATIONAL AREA LIGHT SET: Airfield Runway.				35.0	1,200.0
6210-S03	LIGHT SET OPERATION AREA, AIRCRAFT: Set 6, 1½ kw, Airfield Runway, Portable, Combat.				80.0	3,000.0
6210-S04	LIGHT SET, OPERATIONAL AREA, AIRCRAFT ½kw	24.0	19.0	21.0	5.5	96.0
6230-S01	LIGHT SET: General Illumination, Set 2	54.4	42.8	31.0	41.8	769.6
6230-S04	LIGHT SET: General Illumination, Set 5, 15 kw	107.0	76.0	53.0	249.4	4,050.0
6230-S05	FLOODLIGHT SET: Electric, Portable, Mast Mounted				40.2	650.0
6230-S07	FLOODLIGHT SET: Electric, Portable				.6	26.0
6230-S09	SEARCHLIGHT SET: 60 in. dia. Reflector	252.0	69.0	96.0	966.0	7,325.0
6230-S12	LIGHT SET: Marker, Emergency				5.3	100.0
6605-S01	NAVIGATION SET: Land, Vehicular				10.0	162.0
6605-S02	NAVIGATION SET: Land, Vehicular				3.0	64.0
6230-299-7593	SEARCHLIGHT: 18 in.; 26 v., 2,500 w.; Reflector, w/brackets for tank mtg.					
6630-S01	WATER QUALITY CONTROL SET				6.0	125.0
6630-S02	TEST SET, SOIL: Set 1				58.0	1,611.0
6630-S03	TEST SET, ASPHALT: Set 12				140.0	1,455.0
6630-S04	TEST SET, CONCRETE: Set 13				51.0	1,637.0

6655-S01	ASTRONOMIC POSITION SET			17.0	359.0
6675-S02	COMPUTING AND DRAFTING EQUIPMENT SET			263.8	3,400.0
6675-S03	DRAFTING EQUIPMENT SET: Battalion			13.0	225.0
6675-S12	DRAFTING EQUIPMENT SET: Topographic Battalion, Headquarters and Service Company.			820.0	9,200.0
6675-S13	DRAFTING EQUIPMENT SET: Topographic Battalion, Photomapping Company.			1,940.0	27,700.0
6675-S15	DRAFTING AND DUPLICATING EQUIPMENT SET			3.0	95.0
6675-S16	DRAFTING INSTRUMENT SET: Set 1			1.0	4.0
6675-S17	DRAFTING INSTRUMENT SET: Set 2			.2	2.4
6675-S18T	DRAFTING INSTRUMENT SET: Set 3			.2	1.2
6675-S19	PLOTTING INSTRUMENT SET: Stereoplotter, Multi- plex Control Booth, Set 1.			150.0	4,600.0
6675-S20	PLOTTING INSTRUMENT SET: Stereoplotter, Multi- plex Drafting Unit.			2.0	78.0
6675-S21	PLOTTING INSTRUMENT SET: Stereoplotter, Multi- plex Laboratory.			190.0	4,800.0
6675-S22	PLOTTING INSTRUMENT SET: Stereoplotter, Multi- plex Plotting Booth, Set 4.			60.0	1,380.0
6675-S23	PLOTTING INSTRUMENT REPAIR SET: Stereo- plotter, Projection.			27.0	1,300.0
6675-S24	PLOTTING INSTRUMENT REPAIR SET: Stereo- plotter, Projection.			73.0	704.0
6675-S26	PHOTOGRAMMETRIC EQUIPMENT SET: Engineer Topographic Company, Set 3.			261.0	4,420.0
6675-S27	PHOTOGRAMMETRIC EQUIPMENT SET: Topo- graphic Battalion, Set 1.			1,950.0	30,300.0
6675-S28	PLOTTING SET: Artillery Fire Control			1.4	32.3
6675-S29	REPAIR SET: Surveying Instrument			3.3	98.0
6675-S30	SKETCHING SET: Surveying			1.5	45.0
6675-S31	STEREOMETER SET: Stereocomparagraph, Photogram- metric, Set 1.			15.0	106.0

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
6675-S32	SURVEYING SET: Supplementary Equipment, Topographic Battalion.				20. 0	535. 0
6675-S37	SURVEYING SET: General Purpose				28. 0	474. 0
6675-S38	SURVEYING SET: Plane table				20. 2	260. 0
6675-S39	SURVEYING SET: Precise Baseline, Set 9				10. 0	260. 0
6675-S40	SURVEYING SET: Precise Leveling				2. 0	29. 0
6675-S41	SURVEYING SET: Precise Traversing				22. 0	375. 0
6675-S42	SURVEYING SET: Triangulation Reconnaissance				5. 0	103. 0
6675-S43	SURVEYING SET: Topographic Company				187. 3	3, 561. 0
6675-S44	SURVEYING SET: Triangulation				14. 0	285. 0
6675-S45	SURVEYING SET: Artillery Fire Control 3d Order				2. 0	260. 0
6675-S46	SURVEYING SET: Astronomic Azimuth				N/A	N/A
6675-S47	SURVEYING SET: Artillery Fire Control 4th Order				2. 0	260. 0
6675-S48	MAP DISTRIBUTION SET: Portable				230. 0	4, 400. 0
6675-S49	MAP DISTRIBUTION SET: Depot				3, 615. 1	53, 250. 0
6675-S50	SURVEYING SET: Astronomic Azimuth, Set 20				52. 0	1, 600. 0
6675-S51	CARTOGRAPHIC SECTION: Topographic Mapping Set				2, 420. 0	22, 260. 0
6675-S52	COPY AND SUPPLY SECTION: Topographic Mapping Set.				2, 420. 0	23, 580. 0
6675-S53	RECTIFIER SECTION: Topographic Mapping Set				2, 420. 0	23, 975. 0
6675-S54	MAP REVISION SECTION: Topographic Mapping Set				2, 420. 0	21, 475. 0
6675-S55	MULTIPLEX SECTION: Topographic Mapping Set				2, 420. 0	24, 200. 0
6675-S56	PHOTOMAPPING SECTION: Topographic Mapping Set				2, 420. 0	21, 680. 0
6675-S57	SUPPLEMENTARY EQUIPMENT SET				162. 0	4, 550. 0
6675-S59	DRAFTING EQUIPMENT SET: Plastic Scribing				0. 2	10. 0
6675-S61	SURVEYING SET: Missile Laying				18. 0	240. 0

6910-S02-----	MODEL SET: Camouflage and Fortification, Training Set 1.	-----	-----	-----	29.9	700.0
6910-S03-----	TRAINING AID, MAP READING SET: W/Chest	-----	-----	-----	26.0	450.0
6910-S04-----	MODEL SET: Mine, Training	-----	-----	-----	2.5	35.0
6210-S05-----	MODEL SET: Terrain, Training Aid, W/Chest	-----	-----	-----	13.0	235.0
6910-S06-----	MODEL SET: Mine Training Set 2	-----	-----	-----	3.3	71.0
6910-S04-----	MODEL SET: Mine, Training	-----	-----	-----	2.5	35.0
6910-S05-----	MODEL SET: Terrain, Training Aid, W/Chest	-----	-----	-----	13.0	235.0
6910-S06-----	MODEL SET: Mine Training Set 2	-----	-----	-----	3.3	71.0
6910-S08-----	TRAINING AID SET: Soviet Land Mine, W/Chest	-----	-----	-----	N/A	N/A
7520-S01-----	SIGN PAINTING SET: Set 1	-----	-----	-----	9.0	268.0
7610-S01-----	BOOK SET: Celestial Navigation	-----	-----	-----	.72	29.0
7610-S07-----	BOOK SET: Topographic Battalion	-----	-----	-----	10.5	290.0
7610-S09-----	BOOK SET: Topographic Battalion Photomapping Company.	-----	-----	-----	5.0	140.0
7610-S10-----	BOOK SET: Set 10	-----	-----	-----	1.1	18.0
7610-S13-----	BOOK SET: Water Supply Company	-----	-----	-----	1.1	29.0
7610-S14-----	BOOK SET: Set 15, Forestry Operations	-----	-----	-----	0.6	18.0
7610-S15-----	BOOK SET: Machinist, Welder, and Electrical Repair	-----	-----	-----	0.4	19.0
7610-S16-----	BOOK SET: Combat Group	-----	-----	-----	0.6	31.0
7610-S17-----	BOOK SET: Construction Group	-----	-----	-----	1.4	61.0
7610-S18-----	BOOK SET: Field Army, Engineer Section	-----	-----	-----	0.8	37.0
9905-S01-----	MINEFIELD MARKING SET	-----	-----	-----	84.8	2,800.0
999-S01-----	SUPPLEMENTARY EQUIPMENT: Armored Battalion	-----	-----	-----	89.0	2,394.0
9999-S02-----	SUPPLEMENTARY EQUIPMENT: Camouflage Battalion.	-----	-----	-----	6,000.0	17,500.0
9999-S03-----	SUPPLEMENTARY EQUIPMENT: Aviation Combat Battalion.	-----	-----	-----	369.1	6,250.0
9999-S04-----	SUPPLEMENTARY EQUIPMENT: Forestry Company	-----	-----	-----	1,200.0	30,500.0
9999-S05-----	SUPPLEMENTARY EQUIPMENT: Engineer Construction Battalion.	-----	-----	-----	629.9	13,400.0

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
9999-S06	SUPPLEMENTARY EQUIPMENT: Depot				545.0	47,100.0
9999-S07	SUPPLEMENTARY EQUIPMENT: Aviation Battalion				251.0	4,819.0
9999-S08	SUPPLEMENTARY EQUIPMENT: Separate Battalion				330.0	5,900.0
7610-S13	BOOK SET: Set 14	19.3	13.8	11.0	1.1	35.0
7610-S14	BOOK SET: Set 15	17.3	9.0	12.3	.7	16.0
9905-S01	MINEFIELD MARKING SET				² 78.9	² 21.9
9999-S01	SUPPLEMENTARY EQUIPMENT: Armored Battalion				² 89.0	² 2,394.0
9999-S02	SUPPLEMENTARY EQUIPMENT: Camouflage Battalion.				² 6,000.0	² 17,500.0
9999-S03	SUPPLEMENTARY EQUIPMENT: Aviation Combat Battalion.	132.0	60.0	57.0	261.3	6,300.0
9999-S04	SUPPLEMENTARY EQUIPMENT: Forestry Company				² 1,200.0	² 30,500.0
9999-S05	SUPPLEMENTARY EQUIPMENT: Engineer Construction Battalion.				² 234.0	² 12,100.0
9999-S06	SUPPLEMENTARY EQUIPMENT: Depot				² 545.0	² 47,100.0
9999-S07	SUPPLEMENTARY EQUIPMENT: Aviation Battalion				² 523.2	² 17,650.0
9999-S08	SUPPLEMENTARY EQUIPMENT: Separate Battalion				² 330.0	² 5,980.0
	Chest:					
	Battery, lamp, electric, command post	20.5	17.0	14.5	2.9	25.0
	Bearing ratio equipment				² 27.0	² 118
	Black and white printing equipment				² 8.1	² 82.0
	Blacksmith, engineer	39.0	17.0	10.3	3.1	43.0
	Boat and pontoon repair equipment	31.0	20.8	12.5	3.4	40.0
	Carbon tetrachloride	39.5	14.5	15.0	5.0	46.0
	Carpenter, platoon	42.0	25.0	12.3	5.4	61.5
	Carpenter, squad	41.5	25.0	12.0	5.4	86.0
	Chain hoist, 1-ton				² 4.2	² 49.0

Chain hoist, 1½-ton.....				² 35.0	² 2.4
Chain hoist, 1½-3-ton (2 hoists).....	40.5	20.0	9.0	4.2	49.0
Delineation equipment.....				² 2.3	² 50.0
Diving apparatus, helmet.....	37.5	23.5	19.0	9.7	145.0
Diving apparatus outfit, ES.....	27.3	16.3	10.3	2.6	31.0
Diving apparatus outfit, NS.....	47.3	23.8	21.0	13.7	115.0
Drafting, battalion, coast artillery.....	47.0	25.5	13.0	9.1	70.0
Drafting, battalion, engineer.....	46.0	33.3	12.0	10.6	95.0
Drafting, regimental, coast artillery.....	45.5	35.0	13.0	12.0	98.0
Drafting and duplicating.....	25.5	20.0	93.5	2.7	40.0
Drafting set No. 8, FA flash range.....				² 12.0	² 91.0
Drafting set No. 9, FA sound range.....				² 8.0	² 80.0
Duplicating equipment, gelatin process.....	28.0	21.5	21.0	2.8	60.0
Duplicating equipment, gelatin process.....	25.5	23.3	5.8	1.7	27.1
Duplicating equipment, gelatin process.....	36.5	34.8	12.5	9.2	118.3
Electric lighting equipment, portable: Chest type A.....	40.0	34.3	19.0	15.0	136.0
Electric lighting equipment, portable: Chest type B.....	39.0	27.0	15.0	9.1	50.0
Electric lighting equipment, portable: Chest type "d".....	34.0	19.0	14.0	5.2	34.8
Electric lighting equipment, portable: Chest, 1½-kw. accessories.....				N/A	N/A
Flash point tester.....	42.0	15.5	15.5	5.8	85.0
Kit, repair, small pneumatic floats.....	25.5	19.0	11.3	3.1	30.0
Kit, repair, pneumatic float: Chest A.....	49.0	25.5	19.0	13.7	55.0
Kit, repair, pneumatic float: Chest B.....	32.3	18.5	15.5	5.4	55.0
Kit, repair, pontoon, plywood.....				² 3.4	² 40.0
Kit, repair, pontoon, aluminum or steel.....	31.0	20.8	12.3	3.4	54.0
Lamp, electric, portable, command post.....				² 1.4	² 14.0
Map distribution, type 2.....	44.5	17.3	17.3	8.0	70.0
Minefield marking, set No. 2: Chest No. 1.....				² 4.6	² 60.0
Minefield marking, set No. 2: Chest No. 2.....				² 4.2	² 55.0
Minefield marking, set No. 2: Chest No. 3.....				² 6.8	² 56.0
Miscellaneous bridge parts.....				² 9.6	² 66.0

²Information obtained from Corps of Engineers Technical Committee papers.

Table 3. Sets of Engineer Equipment—Continued

SM 5-4	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu. Ft.	Weight (lb.)
	Chest—Continued					
	Miscellaneous equipment (soil testing)				² 1.0	² 33.0
	Navigation, set No. 1				² 4.9	² 46.0
	Outboard motor, 5 hp	53.0	18.0	18.0	9.9	50.0
	Pioneer equipment, long	68.5	22.0	20.0	11.9	104.0
	Pioneer equipment, short	41.3	16.8	18.5	6.5	73.0
	Pipefitting equipment				² 3.5	² 53.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 1	57.5	35.5	13.5	16.0	120.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 2	34.8	22.5	7.8	3.5	52.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 3				² 3.5	² 65.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 4				² 6.4	² 115.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 5	35.8	35.0	10.5	7.6	58.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 6	34.8	23.4	9.0	4.2	46.0
	Pneumatic tools (315 cfm), set No. 1: Chest No. 7	34.6	22.3	9.0	4.1	50.0
	Pneumatic tools (55 cfm), set No. 1: Chest No. 1				² 15.7	² 110.0
	Pneumatic tools (55 cfm), set No. 1: Chest No. 2				² 2.9	² 30.0
	Pneumatic tools (55 cfm), set No. 1: Chest No. 3				² 2.4	² 35.0
	Pneumatic tools (55 cfm), set No. 1: Chest No. 4				² 3.3	² 39.0
	Pneumatic tools (55 cfm), set No. 1: Chest No. 5				² 3.3	² 35.0
	Printing frame, 24 by 30 in	35.3	30.0	8.0	5.1	50.0
	Rigging equipment	34.8	17.0	9.5	3.2	33.3
	Sign painting equipment				² 7.8	² 68.0
	Sign reproduction kit	31.5	25.8	9.5	3.9	47.8
	Sign storage	38.0	19.0	19.0	7.5	60.0
	Soil sampling equipment, field laboratory				² 4.4	² 43.0
	Soil testing equipment, field laboratory				² 1.0	² 33.0
	Surveying, set No. 2, FA flash range				² 7.5	² 68.0

Surveying, set No. 3, FA sound range-----				² 9.8	² 68.0
Surveying, set No. 5, FA topographic-----				² 2.6	² 40.0
Tool, machinist, wood w/7 drawers-----	17.8	13.5	9.5	1.2	15.5
Tool, machinist, pioneer-----	27.5	20.0	10.8	2.4	38.0
Tool, master mechanic, steel-----	26.0	12.5	11.5	2.0	43.0
Tools and foot walk-----				² 12.6	² 97.0
Tool kit, set No. 5-----	19.5	14.0	7.0	1.0	10.7
Topographic equipment, field artillery-----	33.3	25.5	9.5	4.6	58.0
Water quality control, set No. 1-----	21.8	18.8	12.8	3.0	54.0
Wire rope repair, set No. 9: Chest No. 1-----	28.5	20.5	15.5	4.9	51.0
Wire rope repair, set No. 9: Chest No. 2-----	29.5	28.0	11.3	5.0	41.6

² Information obtained from Corps of Engineers Technical Committee papers.

7. Radio Facilities of Engineer Units

The radio sets available to or associated with engineer troop units, with their frequencies, emissions, normal ranges, and normal usage, are listed in table 4. Common abbreviations used in radio nomenclature are as follows:

a.c.-----	alternating current	LV-----	low voltage
AF-----	audio frequency	m.c.w-----	modulated continuous wave
AM-----	amplitude modulation	RF-----	radio frequency
BA-----	battery	mc-----	megacycles
c.p.s-----	cycles per second	rcvr-----	receiver
c.w.-----	continuous wave	RT-----	receiver-transmitter
d.c.-----	direct current	SW-----	sky wave
FM-----	frequency modulation	v-----	volt
f.s.-----	frequency shift	VF-----	voice frequency
GN-----	generator	w-----	watt
HF-----	high frequency	xmtr-----	transmitter
HV-----	high voltage	f.s.k-----	frequency shift keying
LF-----	low frequency		

Table 4. Radio Sets

Radio set	Frequency (megacycles)	Emission and range (miles)	Normal use	Remarks
AN/PRC-6-----	47.0-55.4-----	Voice: FM (1)-----	Combat and airborne company: brigade platoon and section; dismounted tactical units.	It is shaped like a telephone, but it can be shoulder-slung and operated with an attached handset.
AN/PRC-8-----	20.0-27.9-----	Voice: FM (3)-(5)-----	Armored company, battle group and division level.	Man-carried field radio—for vehicle operation, amplifier-power supply AM-598/U required.
AN/PRC-9-----	27.0-38.9-----	Voice: FM (3)-(5)-----	Artillery units-----	Same as AN/PRC-8.
AN/PRC-10-----	38.0-54.9-----	Voice: FM-----	Infantry combat and airborne units.	Same as AN/PRC-8.
AN/GRC-3-----	20.0-27.9-----	Voice: FM Stationary (15). Moving (10).	Armored units-----	Can be installed in truck, personnel carrier, tanks, utility vehicles, etc.
RT-70/GRC-----	47.0-58.4-----	Voice: FM (1).		
R-108/GRC-----	20.0-28.0-----			
AN/GRC-4-----				
AN/GRC-7-----	38.0-54.9-----	(Same as AN/GRC-3 less auxiliary receiver R-108/GRC) Voice: FM Stationary (15). Moving (10).	Infantry units-----	Can be installed in truck, personnel carrier, tanks, utility vehicles, etc.
RT-70/GRC-----	47.0-58.4-----	Voice: FM (1).		
R-110/GRC-----	38.0-55.0-----			
AN/GRC-8-----				
AN/GRC-9-----	2.0-12.0-----	(Same as AN/GRC-7 less auxiliary receiver R-110-GRC) AM-stationary: c.w. (30); m.c.w. (20). Voice (15). Moving: c.w. (20); m.c.w. (10). Voice (10).	Infantry and armored motorized elements, engineer combat battalion.	Ground or vehicle-operated two-way radiotelephone and radiotelegraph between stationary and moving radios.
AN/GRC-19-----	1.5-20.0-----	AM-Voice (50). f.s., c.w. (75). Sky wave (150)-(1500).	Division, corps and army, engineer combat battalion to higher headquarters and reconnaissance.	Forward area vehicular set. Replaces SCR-193 and SCR-506. Provides communication between vehicles from vehicle to
	revr .5-32.0.			

Table 4. Radio Sets—Continued

Radio set	Frequency (megacycles)	Emission and range (miles)	Normal use	Remarks
				air or ground set. Voice and radio teletype service at the same time is possible when connected to radio-teletype equipment which is not supplied as a part of the GRC-19. (See GRC-26 below.)
AN/GRR-5. ---	1.5-18.0. ---	Receives voice; m.e.w.; e.w.; low-power AM.	Engineer units requiring an aircraft warning net. Normally infantry division.	Receiver only, used generally for warning networks. Portable or vehicular mounted.
SCR 506-A. ---	2.0-4.5. ---	AM-stationary: e.w. (75). Voice (25).	Armored elements. ---	General-purpose vehicular set. Can be used by all motorized tactical units for ground to ground, ground to air.
	revr 2.0-6.0. ---	Moving: e.w. (35). Voice (15).		
AN/VRC-7. ---	47.0-58.4. ---	FM-voice (1). ---	Artillery, armored, and infantry elements.	Separate installation of set 2 of GRC-3 to -8 series. For very-short-range operation within and between armored, artillery and infantry units.
AN/VRC-8. ---	20.0-27.9. ---	FM-voice: Stationary (15). Moving (10).	Normally armored elements. ---	Same as GRC-4, except RT-70/GRC and remote-control or retransmission facilities are not provided.
AN/VRC-9. ---	27.0-30.9. ---	(Same as	AN/VRC-8)	
AN/VRC-10. ---	38.0-54.9. ---	FM-voice: Stationary (15). Moving (10).	Normally infantry and supporting elements.	Same as GRC-8, except RT-70/GRC and remote-control or retransmission facilities are not provided.

AN/VRC-16-----	20.0-27.9-----	FM-voice: Stationary (15). Moving (10).	Normally armored and supporting elements.	Same as GRC-3, except RT-70/GRC and remote-control or retransmission facilities are not provided.
R-108/GRC-----	20.0-28.0-----			
AN/VRC-18-----	38.0-54.9-----	FM-voice: Stationary (15). Moving (10).	Normally armored elements. Also used by artillery and infantry and supporting elements.	Same as GRC-3, except RT-70/GRC and remote-control or retransmission facilities are not provided.
R-110/GRC-----	38.0-55.0-----			
AN/VRQ-1-----	20.0-27.9-----	FM-voice: Stationary (15). Moving (10).	Armored and supporting elements.	Basically 2 AN/VRC-8's on single mounting.
AN/VRQ-2-----	27.0-38.9-----	FM-voice: Stationary (15). Moving (10).	Artillery. Also between artillery, infantry, and armored elements.	Basically 2 AN/VRC-9's on single mounting. Normally used for relay or retransmission.
AN/VRQ-3-----	38.0-54.9-----	FM-voice: Stationary (15). Moving (10).	Infantry. Also between artillery and infantry elements.	Basically 2 AN/VRC-10's on single mounting. Point-to-point, retransmission, or radio relay between artillery and infantry elements.
AN/GRC-26-----	2.0-18.0----- rcvr 1.5-18.0	AM-f.s. radio-teletype, c.w. Voice (1,000).	Corps and division level-----	Mobile medium powered, long range, point to point, and ground to air. Equipment includes teletypewriter radio receiver and transmitter, perforator transmitter, frequency shift exciter, dual diversity converter, and associated items installed in a field type shelter mounted on a 2½-ton, 6 by 6 cargo truck, with a 1-ton trailer on which a portable field powered unit is installed.
AN/GRC-46-----		AM-f.s. radio-teletype, c.w. Voice:	(ROCID) infantry division nets to include division engineer battalion.	Same as GRC-19, with radio-teletype facilities. Mounted in ¾-ton truck.

8. Equipment of Other Supply Services

Tables 5 through 9 give weights and cubages of major items of equipment supplied by services other than the Corps of Engineers, which are of especial interest to engineer units. Data are for crated items except in the case of Signal Corps equipment (table 9). For items of ordnance equipment not listed in table 7, see paragraphs 10 and 30.

Table 5. Chemical Equipment (Crated)

Item	Cubic feet	Weight, pounds
Decontaminating Apparatus.....	4. 35	37. 50
Detector Kit, M9A2.....	. 26	6. 25
Mask, Gas, M11A1.....	. 73	12. 33
Mask, Protective Field, M9A1.....	. 55	9. 33
Respirator, Air, Dust.....	. 02	. 32
Respirator, Air, Paint Spray.....	. 34	5. 83
Water Testing Kit, M4.....	1. 30	55. 00

Table 6. Medical Equipment (Crated)

Item	Cubic feet	Weight, pounds
Blanket Set, Small.....	3. 10	32. 00
Dental Equipment Set, Field.....	6. 25	150. 00
Dental Instrument and Supply Set.....	. 81	15. 13
Evacuation Bag, Complete.....	3. 00	32. 50
Light, Surgical, Field, Battery Operated.....	3. 76	90. 00
Light, Surgical, Bracket, Battery Operated.....	. 60	12. 00
Litter, Folding, Rigid, Aluminum.....	1. 43	23. 00
Litter, Folding, Aluminum Pole.....	1. 25	25. 00
Medical Instrument and Supply Set Dispensary, Field.....	2. 00	70. 00
Medical Supply Set, Supplemental Supplies.....	2. 30	45. 00
Otoscope and Ophthamoscope Set.....	. 17	3. 78
Pail, Metal, 12 Quart.....	1. 63	14. 50
Sphygmonanometer Aneroid.....	. 09	1. 71
Splint Set, Telescope Splints.....	1. 25	18. 50
Stove, Gas Burner, w/case.....	. 48	16. 33
Surgical Instrument Supply.....	1. 50	47. 00
Surgical Instrument and Supply Set, Individual.....	. 60	9. 55

Table 7. Ordnance Equipment (Crated)

Item	Cubic feet	Weight, pounds
Cabinet, Spare Parts Type III, C1B-----	29. 75	378. 00
Chain Assembly, Sgic Leg, ¾ in. by 16 ft-----	. 50	70. 00
Demounter, Pneumatic Tire, Hydraulic-----	10. 60	300. 00
Mount, Machine Gun, Cal. 30, M48, W/EQP-----	2. 40	65. 00
Mount, Machine Gun, AA, Cal. 50, M63, W/EQP--	8. 10	170. 00
Mount, Tripod, Machine Gun, Cal. 30, M2, W/EQP-	1. 90	25. 00
Mount, Tripod, Machine Gun, Cal. 50, M3, W/EQP-	2. 00	44. 00
Mount, Tripod, Machine Gun, 7.62 MM, M91-----	2. 00	40. 00
Mount, Truck, Pedestal, M24A2-----	10. 60	253. 00
Tool Kit, Armorers-----	2. 42	48. 00
Tool Kit, Automotive Fuel and Elec Sys Rpmn----	1. 61	22. 45
Tool Kit, Electricians No. 1-----	4. 74	82. 28
Tool Kit, Electricians No. 2-----	. 35	13. 00
Tool Kit, General Mechanics-----	2. 00	69. 00
Tool Kit, Instrument Repairman-----	1. 81	50. 36
Tool Kit, Metal Body Repairman-----	. 76	37. 50
Tool Kit, Organizational Maintenance No. 1 Com-		
mon-----	41. 70	858. 00
Tool Kit, Organizational Maintenance No. 1 Supple-		
mental-----	36. 80	871. 00
Tool Kit, Organizational Maintenance No. 2 Com-		
mon-----	276. 00	2, 425. 00
Tool Kit, Organizational Maintenance No. 2 Supple-		
mental-----	130. 80	3, 076. 00
Tool Kit, Organizational Maintenance Set No. 7----	65. 00	935. 00
Tool Set, Machinist-----	1. 33	48. 00
Tool Set, Organizational Maint Army Aircraft-----	59. 00	930. 00

Table 8. Quartermaster Equipment (Crated)

Item	Cubic feet	Weight, pounds
Bag, Water Sterilizing-----	1. 34	20. 40
Bag, Ammunition-----	. 08	2. 00
Calculating Machine-----	1. 04	35. 00
Can, A-G, 10 gal. cap-----	1. 01	13. 83
Can, A-G, 24 gal. cap-----	3. 32	26. 67
Can, A-G, 32 gal. cap-----	4. 57	32. 33
Can, Water, 5 gal-----	. 94	10. 00
Chest, Music, Fiber-----	2. 89	26. 00
Cooking Outfit, 1 brn-----	. 26	5. 17
Desk, Field, type 11-----	4. 28	54. 00
Duplicating Machine, Hand Opr-----	12. 65	204. 00
Duplicating Machine, Mtr. Dvn-----	28. 63	326. 00
Duplicating Machine, Spirit Proc-----	2. 98	65. 00
Lantern, Gas, 1½ pt-----	. 64	9. 37
Machine, Computing, 10 Column-----	3. 08	65. 00
Paulin, Duck, OD, 20 by 40 ft-----	4. 90	192. 00
Paulin, Duck, OD, 12 by 17 ft-----	1. 65	50. 67

Table 8. Quartermaster Equipment (Crated)—Continued

Item	Cubic feet	Weight, pounds
Range, Field, M1937B Pack.....	18. 50	340. 00
Roll, Commissary, Complete.....	3. 49	65. 00
Safe, Field.....	5. 89	185. 00
Scale, Plat, 300 lb.....	4. 08	134. 00
Screen, Latrine, Complete.....	1. 42	45. 00
Sling, Flagstaff.....	. 19	3. 19
Stencil Cutting Machine, 1 in.....	11. 14	190. 00
Stencil Outfit.....	. 51	65. 50
Typewriter, Non-Ptbl, 11 in.....	4. 13	76. 00
Typewriter, Non-Ptbl, 14-15 in.....	5. 21	60. 00
Typewriter, Non-Ptbl, 18-19 in.....	4. 90	80. 00
Typewriter, Non-Ptbl, 26-27 in.....	8. 39	125. 00
Typewriter, Ptbl w/carrying case.....	1. 50	32. 00

Table 9. Signal Equipment (Uncrated)

Item	Cubic feet	Weight, pounds
Amplifier, AM-598/U.....	0. 94	35. 95
Axle, RL-27.....	. 12	5. 50
Battery, BB-50.....	. 50	64. 00
Camera, PH-324.....	. 02	. 94
Camera, PH-691/U.....	. 46	15. 00
Camera, KS-7.....	64. 00	292. 00
Channel Alignment Indicator ID-292/PRC.....	. 02	1. 30
Chest, BC-5.....	3. 78	35. 00
Chest, CY-250/U.....	6. 58	35. 00
Chest Set, H-12/GT.....	. 04	2. 22
Chest Set, H-18/GT.....	. 20	3. 40
Code Tr'ng Set AN/GSC-T1.....	1. 31	40. 00
Coil, C-161.....	. 13	3. 00
Converter, M209.....	. 08	6. 00
Electronic Multimeter TS-505/U.....	. 34	15. 00
Emergency Switchboard SB-18/GT.....	. 09	2. 25
Exposure Meter PH-260.....	. 01	1. 00
Flashlight MX-212/U.....	. 01	. 50
Flashlight MX-991/U.....	. 02	. 06
Frequency Meter SCR-211.....	. 96	39. 50
Hand Set TS-10.....	. 20	1. 90
Head Set HS-30.....	. 04	. 57
Linemen's Equipment TE-21.....	. 96	21. 00
Microphone.....	. 01	. 09
Multimeter AN/PRM-15.....	. 12	5. 00
Oscilloscope OS-8/U.....	. 43	14. 50
Photo Equipment PH-383.....	10. 00	333. 00
Power Unit PE-162.....	1. 91	56. 00
Radiac Meter IM-93/UD.....	. 01	. 07
Radio Set AN/GRC 9.....	17. 00	135. 00

Table 9. *Signal Equipment (Uncrated)*—Continued

Item	Cubic feet	Weight, pounds
Radio Set AN/PRC 10.....	1. 37	18. 00
Radio Set AN/PRC 6.....	. 16	3. 50
Radio Set AN/VRC 10.....	3. 09	138. 00
Radio Set AN/VRC 8.....	3. 09	138. 00
Radio Set AN/VRC 16.....	3. 09	138. 00
Radio Set SCR-193.....	3. 60	114. 00
Radio Set AN/GRA.....	. 98	17. 50
Radio Receiving Set AN/TRR-8.....	2. 43	26. 00
Reel Equipment CE-11.....	1. 13	17. 00
Reel Unit RL-31.....	5. 00	100. 00
Spool DR-8.....	. 38	2. 00
Switch Board SB-22/PT.....	2. 56	37. 10
Telephone Set TA 264/PT.....	. 66	25. 00
Telephone Set TA 312/PT.....	9. 50	. 18
Telephone Central Office Set TC-4.....	18. 64	440. 40
Teletypewriter Set AN/PGC-1.....	20. 00	451. 00
Terminal Telegraph.....	. 91	51. 00
Test Set TS-26/TSM.....	. 23	8. 00
Test Set Electron Tube TV-7/U.....	. 46	18. 00
Timer Interval FM 17.....	. 07	2. 00
Tool Equipment TE 33.....	. 03	3. 00
Tool Equipment TE 41.....	. 52	16. 00
Tool Equipment TK 28/GF.....	. 80	17. 00
Tube Tester.....	. 44	41. 00
Vibrator Pack PP-68/U.....	. 40	22. 00
Wire pike.....	. 50	6. 00
Wire WD-1/TT on Reel DR-4.....	1. 94	70. 00
Wire WD-1/TT on Reel DR-5.....	3. 30	82. 00
Wire WD-1/TT on Spool DR-8.....	. 38	14. 00

Section II. MOTORIZED AND HEAVY EQUIPMENT

9. Engineer Motorized and Heavy Equipment

The make, model, stock number, overall dimensions, weight in pounds, and cubage of the various items of engineer motorized and other heavy equipment, and the aircraft in which they are transportable, are given in table 10. Data are for working conditions.

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment

Item	Make, model and stock No.	Dimension in inches			Weight in pounds	Cubic feet	Transporting aircraft
		Length	Width	Height			
Mixer, Bituminous: G.D. 10, 30 tons/hour. Unit 1 Mixer, Bitum. Trl. Mtd. Comm. 3895.221.1805.	Barber Greene Model 840. 3895.221.1811.	182. 0	88. 0	116-----	11, 610	1, 075. 1	C-97 C-130 C-119 C-123 C-133 C-124
Drier, Aggregate: G.D. 10-30 tons/hour. Unit 2 Dry'r Aggreg. Trl. Mtd. Comp. 3895.274.5035.	Barber Greene Model 830. 3895-634-9178.	146. 0	108. 0	217-----	13, 325	1, 980. 1	C-119 C-130 C-123 C-124 C-133
	Barber Greene Model 839. 3895-634-8098.	276. 0	118. 0	132-----	18, 000	2, 487. 0	C-119 C-130 C-123 C-124 C-133
Boat: Gas Powered 27/ft. Two section. Aluminum.	All makes and models. 1940-271.9726	142. 0	97. 0	80-----	(bow) 1, 150	518. 1	C-97 C-130 C-119 C-133
		189. 0	97. 0	80-----	(stern) 4, 750	848. 8	C-123
Compressor: Air, Trailer Mtd. w/wheels. Pneumatic tires, DD. 315 CFM. 4310.203. 0569.	Ingersoll-Rand Model IK-315. 4310.265.-3158.	153. 0	63. 0	89-----	5, 900	496. 5	C-124
					8, 500		C-97 C-130 C-119 C-123 C-133 C-124
Compressor: Air, Trailer Mtd. 4 wheels—Pneumatic tires, DD. 630 CFM. 4310.203.-0569.	Le Roi Model 600D2 MOD. 4310.265.7929.	156. 0	84. 0	96-----	11, 000	728. 0	C-97 C-130 C-119 C-123 C-133 C-124

Compressor: Air, Trailer Mtd. 4 wheels—Pneumatic tires, DD. 315 CFM. 4310.203.- 0569.	Ingersoll-Rand Model DR-315 Gyro-Flo. 4310.270.3332.	120.0	67.0	85-----	6,000	450.0	C-97 C-130 C-119 C-123 C-124 C-133
Compressor: Air, Trailer Mtd. 4 wheels—Pneumatic tires, DD. 600 CFM. 4310.203.- 0569.	Jaeger: Model Eng. 600. 4310.620.4056.	157.0	75.0	99-----	10,000	700.0	C-97 C-130 C-119 C-123 C-124 C-133
Compressor: Air, Truck Mtd. GD 210 CFM. 4310.542.- 4408.	Le Roi Model 210 GI. 4310.273.8563.	284.0	96.0	93-----	16,300	1,569.0	C-119 C-130 C-123 C-124 C-133
Compressor, Rotary: Air, Skid, Mtd. 125 CFM, 100 PSI. 4310.542.5783.	Le Roi Model 105GA. 4310.132.6365.	269.0	90.0	93-----	15,100	1,303.0	C-119 C-130 C-123 C-124 C-133
Crane: Shovel, Truck Mtd. GD, 20 ton, $\frac{3}{4}$ Cu. Yd. 3810.554.4103.	Lima Model 34T. 3810.189.9691. CAB.	160.0	96.0	94-----	27,150	835.6	C-124 C-133 C-124 C-133
	Lima F. W. D. MUC 6 by 6. Carrier.	302.0	103.0	109-----	30,050	1,944.1	C-19 C-130 C-123 C-124 C-133
	Garwood-Buckeye Model M-20-A. 3810.189.- 9694. CAB.	156.0	99.0	96-----	53,000	2,660.7	C-119 C-130 C-123 C-124 C-133
	Garwood-Buckeye F. W. D. MUC., 6 by 6. Carrier.	302.0	103.0	109-----	29,370	1,944.1	C-119 C-130 C-123 C-124 C-133
	Koehring Model 304. 3810.240.7505.	173.0	108.0	96-----	55,300	2,936.0	C-119 C-130 C-123 C-124 C-133
	Koehring F. W. D. MUC., 6 by 6. Car- rier.	302.0	103.0	109-----	31,225	1,944.1	C-119 C-130 C-123 C-124 C-133

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued

Item	Make, model and stock No.	Dimension in inches			Weight in pounds	Cubic feet	Transporting aircraft	
		Length	Width	Height				
Crane—Continued	Bucyrus Erie Model 22B. 3810.189.9692. CAB.	147. 0	96. 0	94-----	21, 090	767. 7	C-119	C-130
	Bucyrus Erie F.W.D. MUC., 6 by 6. Carrier.	302. 0	103. 0	109-----	26, 100	1, 944. 1	C-123	C-133
Crane: Non-revolving, Tractor Oper. Wheeled, 40,000 Cap. 20 ft. Boom. 3810.234.5118.	Le Tourneau Model M-20. 3810.234.5119.	330. 0	115. 0	230-----	8, 400	5, 051. 2	C-119	C-130
							C-123	
Crusher, Jaw: Rock, Airborne. 15 TPH Capacity. 3820.286. 9190.	Iowa Unit. 3820.030.1612 Iowa Unit. AB-1524-SP-15T.	224. 0	80. 0	92-----	16, 000	954. 0	C-124	C-133
							C-97	C-130
Distributor: Bituminous Mat'l. Trailer Mounted. 1,250 Gal. 3895.194.5927.	Entyre Model MX, Style RE. 3895.-194.5937.	194. 0	92. 0	102-----	11, 500	1, 053. 5	C-119	C-130
							C-123	
Distributor: Bituminous Mat'l. Truck Mounted. 800 Gal. 3895.663.4680.	Entyre Model MX, Style RE. 3895.641.6025.	328. 0	96. 0	99-----	22, 300	1, 804. 0	C-124	C-133
							C-119	C-130
Distributor: Water. Truck Mounted. 1,000 Gal. 3825.-275.2622.	Rosco Model MDE. 3825.383.7133.	266. 0	97. 0	105-----	19, 820	1, 567. 8	C-123	C-133
	Tank Assem-----	140. 0	97. 0	82-----		644. 4	C-119	C-130
	Chassis-----	260. 0	94. 0	105-----		1, 485. 1	C-124	C-133
						2, 129. 5		

Generator Set: Portable, Diesel. Skid Mounted, 15 KW., 127-220 Volt, 3 phase, 60 cycle or 230-400 Volt, 3 phase, 50 cycle. 6115.235.8681.	Ready Power Model RD-6-A 12. 6115.236.9995.	84.0	30.0	53-----	3,455	77.3	C-97 C-130 C-119 C-123 C-124 C-133
Generator Set: Portable, Diesel, Engine-Driven, Skid Mount- ed, 30 KW., 127-220 Volt, 3-phase, 60 cycle, or 230-400 Volt, 3 phase, 50 cycle. 6116.635.9955.	Buda Model 6DTG-317. 6115.242.2295.	91.0	25.0	50-----	2,995	65.8	C-97 C-130 C-119 C-123 C-124 C-133
Grader: Road, Motorized, Die- sel, 12 ft. Mold Board. 3805.238.5108.	Caterpillar Model 12. 3805.261.5826.	310.0	97.0	91-----	23,320	1,583.5	C-119 C-130 C-123 C-124 C-133
	Austin-Western Model 99H. 3805.261.5825.	291.0	95.0	104-----	22,000	1,663.8	C-119 C-130 C-123 C-124 C-133
Kettle: Asphalt, Repair, Trailer Mounted w/Motor Driven Hand Spray, 110 Gal. capac- ity. 3895.247.7592.	Littleford Model US-66. 3895.247.7591.	116.0	53.0	46-----	1,262	163.7	C-97 C-130 C-119 C-123 C-124 C-133
Kettle: Asphalt, Repair, Trailer Mounted w/Motor Driven Hand Spray, 165 Gal. capac- ity. 3895.247.7592.	Littleford Model 84-HD-3. 3895.247.7594.	132.0	64.0	65-----	1,500	317.7	C-97 C-130 C-119 C-123 C-124 C-133
Kettle: Asphalt, Skid Mounted, w/Gas Powered Circulating Pump, 750 Gal. capacity. 3895.292.0078.	Rosco Model KO. 3895.252.1183.	152.0	85.0	54-----	6,500	403.7	C-97 C-130 C-119 C-123 C-124 C-133

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued

Item	Make, model and stock No.	Dimension in inches			Weight in pounds	Cubic feet	Transporting aircraft	
		Length	Width	Height				
Lubricator: 1¼ ton, Trailer Mounted.	Grey Mfg. Co. No stock number.	167.0	84.0	88-----	5,700	714.4	C-97 C-119 C-123	C-130
Mixer: Concrete, Gas Driven, Trailer Mounted, Side Discharge, 4 wheels, 14 cu. ft. 3895.286.1145.	Ransome Model 14 SU. 3895.264.4810.	121.0	88.0	120-----	5,970	739.4	C-124 C-97 C-119 C-123	C-133 C-130
Mixer: Concrete, Gas Driven, Air Cooled, End Discharge, Trailer Mounted, 4 Pneumatic Tired Wheels, 16 cu. ft. 3895.238.5094.	Construction Mach. Co. Model 16S. 3895.255.4134.	115.0	98.0	127-----	5,780	828.3	C-124 C-119 C-123	C-133 C-130
Roller: Road, Towed Type, Sheeps Foot, 2 Drums, in line. 3895.263.0121.	Le Tourneau Model W-2. 3895.250.6054.	175.0	113.0	58-----	6,040	663.7	C-97 C-119 C-123 C-124	C-130
Roller: Road, Towed Type, Wheeled, 13 Pneumatic Tires. 3895.227.1599.	William Bros. Model 67W. 3895.243.5442.	174.0	89.0	46-----	3,550	412.2	C-97 C-119 C-123 C-124	C-133 C-130
Roller, 7½ Ton: Road, Towed Type, Wheeled, 4 Pneumatic Tires. 3895.641.7761.	Grace Model Wltr. 3895.243.2678.	288.0	96.0	92-----	19,000	1,472.0	C-124 C-119 C-123	C-133 C-130
	William Bros. Model 450 Mod. 3895.-223.8412.	298.0	96.0	92-----	14,800	1,523.1	C-124 C-119 C-123	C-133 C-130

Roller: Road, Powered, 10 ton, Gasoline, 3 Wheel. 3959.223. 8397.	Galion Model "Chief". 3895.194.8555.	205. 0	77. 0	110-----	20, 200	1, 004. 8	C-97 C-119 C-123 C-124 C-119 C-123 C-124	C-130 C-133 C-130 C-133
Rooter: Road, Cable Operated, 3 Tooth.	Le Tourneau Model H-3. 3895.234.2545.	204. 0	100. 0	67-----	7, 500	791. 0	C-119 C-123 C-124	C-130 C-130 C-133
Seraper: Road, Towed Type, Cable Operated, 8 cu. yd. 3805.197.8574.	Le Tourneau Model LS. 3805.197.8579.	355. 0	118. 0	120-----	14, 000	2, 909. 0	C-119 C-123 C-124	C-130 C-130 C-133
Seraper: Road, Towed Type, Cable Operated, 12 cu. yd. 3805.261.5849.	Le Tourneau Model LP. 3805.197.8584.	384. 0	123. 0	133-----	19, 700	3, 635. 3	C-119 C-123 C-124	C-130 C-130 C-133
Scraper: Road, Towed Type, Cable Operated, 12 cu. yd. 3805.197.8582.	Le Tourneau Model FU. 3805.378.9807.	376. 0	137. 0	130-----	20, 400	2, 875. 3	C-119 C-123 C-124	C-130 C-130 C-133
Shop Equipment: Contact Main- tenance, Mobile Shop, Mtd. on ¾ ton M56 Ordnance Chassis. 4940-294-9518.	Body by: McCare Powers Auto Body Shop. No stock number.	214. 0	83. 0	89-----	8, 980	914. 8	C-119 C-123 C-124	C-130 C-130 C-133
Shop Equipment: General Pur- pose, Truck.	Motorized. No spe- cific make or model. 4940-294-9516.	268. 0	93. 0	115-----	16, 455	1, 658. 7	C-119 C-123 C-124	C-130 C-130 C-133
Shop Equip.: Org. Repair, Heavy, semi trailer, Mounted. 4940-287-4894.	Semi-Trailer. No spe- cific make or model.	324. 0	95. 0	129-----	23, 000	2, 297. 8	C-119 C-123 C-124	C-130 C-130 C-133
	(Complete Unit)	252. 0	97. 0	88-----	16, 870	1, 244. 8	C-124	C-133
	(Body)	324. 0	95. 0	41-----	6, 130	730. 3		
	(Trailer Bed)							

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued

Item	Make, model and stock No.	Dimension in inches			Weight in pounds	Cubic feet	Transporting aircraft
		Length	Width	Height			
Scraper: Road, Motorized, Cable Operated, 11 to 12 cu. yd. 3805.276.7616.	Le Tourneau Model Super C Tournapull. w/Model LP Carryall. 3805.281.1892.	155.0	95.0	90-----	13,400	766.9	C-119 C-130 C-123
		264.0	122.0	142-----	19,500	2,646.7	C-124 C-133 C-119 C-130 C-123 C-124 C-133
Roller: Road, G.D., Tandem, 3 Axle 9-14 ton. 3895.194.8544.	Buffalo-Springfield Model KX-16. 3895.194.8544.	268.0	63.0	87-----	18,770	850.1	C-97 C-130 C-119 C-123 C-124 C-133
		248.0	67.0	85-----	21,539	817.3	C-97 C-130 C-119 C-123 C-124 C-133
	Galion Model 3T9G. 3895.641.6414.						C-97 C-130 C-119 C-123 C-124 C-133
Sawmill: Portable, G.D., Head Block Type, 4 by 7 ft., 60 in. Diameter Saw. 3210.287.4144.	Corinth Model 2C. 3210.242.4493.				25,860		C-97 C-130 C-119 C-123 C-124 C-133
							C-97 C-130 C-119 C-123 C-124 C-133
Tractor: Wheel, Pneumatic, Diesel, Special, 20,025-27,000 DBP. 2420.190.0325.	Le Tourneau Model Super C Tornado- dozer. 2420.277.- 9593.	204.0	121.0	100-----	31,700	1,428.5	C-124 C-130 C-133
Shovel: Front, for Crane Shovel Truck Mtd., 20 ton, ¾ yd.	Lima. 3815.227.6245	266.0	39.0	65-----	6,500	390.2	C-97
	Garwood-Buekeye. 3815.641.7478.	216.0	39.0	65-----	6,340	316.9	C-119 C-123
	Koering. 3815.246.4403.	247.0	51.0	50-----	6,480	364.5	C-124 C-130

	Bucyrus-Eric. 3815.227.6233.	234.0	39.0	82-----	6,340	433.1		C-133
Dolly-----	Eidel-Model Efld-40. 2330.188.0088.	104.0	115.0	57-----	8,650	394.5	C-124	C-130 C-133
	Assem. Totals-----	480.0	115.0	77-----	32,550	2,459.7		
Tank: Asphalt, Steel, Trailer Mounted, w/Steam Coils, 1,500 gal. 2330.294.6509.	Little Ford Model 102 S. 2330.391.0521.	231.0	96.0	114-----	10,130	1,463.0	C-119 C-123	C-130 C-133
Tractor: Crawler, Diesel, 8,600- 12,000 DBP, w/Bulldozer Tilt, Hydraulic Front Mtd., Winch, Towing, Reversible, rear, 1 Drum. 2410.260.3944.	Caterpillar, Model D4	144.0	99.0	70-----	16,062	577.5	C-97 C-119 C-123 C-124	C-130 C-133
Tractor, Crawler Type, Diesel Driven, 12,000-1,700 Lbs. DBP, w/Bulldozer Tilt, Power Control Unit, Fr. Mtd., Winch Reversible, Rear Mtd., 1 Drum.	Caterpillar Model D6. 2410-190-0044.	190.0 (Blade)	142.0 (Str.)	76-----	22,755	1,186.6	C-97 C-119 C-123 C-124	C-130 C-133
Tractor: Crawler Type, Diesel Driven, 17,000-24,000 Lbs. DBP, w/Angle Dozer, Power Control Unit, Front Mtd. Cable, Operating, 1 Drum & Winch Reversible, Rear Mounted, 1 Drum.	Caterpillar Model D7. 2410.268.8634.	219.0	152.0	97-----	35,676	1,858.6	C-119 C-123 C-124	C-130 C-133
Tractor: Crawler Type, Diesel Driven, 28,100-38,000 Lbs. DBP, w/Bulldozer, Tilting, Cable Oper, Power Control Unit, Cable Operating, Front Mtd., 1 Drum, Power Control Unit, Cable Operating, Rear Mounted, 2 Drums.	Caterpillar Model D8 2-U Series. 2410.233.5751 and Model D89A Series. 2410.542.4881, 2410- 542.4882.	236.0	160.0	90-----	46,787	1,966.7	C-124	C-130 C-133
		236.0	160.0	90-----	53,175	1,966.7	C-124	C-130 C-133

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued

Item	Make, model and stock No.	Dimension in inches			Weight in pounds	Cubic feet	Transporting aircraft
		Length	Width	Height			
Tractor: 4 Wheels, Rubber Tired, DED, 27,022-38,000 lbs. DBP, Power Control Unit, 2 Drums. 2420.200.1297.	Caterpillar DW20M. 2420.200.1297.	229.5	112.4	Reducible to 114.5.	49,020	1,923.0	C-119 C-123 C-124 C-130 C-133
Tractor: Wheeled, Rubber Tired, Industrial, DED, 20,025-27,000 lbs. DBP, Cable operated, Rear Mounted, 2 Drums, Weight Transfer Device. 2420.287.5256.	MRS 190. 2420.287.5250.	194.0	100.0	Reducible to 96.	29,000	1,451.9	C-119 C-123 C-124 C-130 C-133
Tractor: Wheeled, Rubber Tired, Industrial, DED, 14,025-20,000 lbs. DBP. 2420.517.0675.	MRS 150. 2420.517.0675.	194.0	96.0	115-----	Unknown	Unknown	C-119 C-123 C-124 C-130 C-133
Tractor: Crawler Type 8,600-12,000 lbs. DBP, w/Loader Hydraulic Operated, Front Dump, ¾ cu. yd. Bucket.	Allis-Chalmers Model HD-5G. 2410.229.9459.	174.0	73.0	71.5-----	16,540	525.6	C-97 C-130 C-119 C-123 C-124 C-133
Trailer: 4 wheel, Tandem, 4 Double Tire, Flat Bed, for Crane Shovel Attachment, 10 ton.	All makes and models. 2330.377.0389.	335.0	98.0	60-----	11,750	1,139.9	C-119 C-130 C-123 C-124 C-133
Trailer: Full Low Bed, 8 ton---	All makes and models. 2330.273.4421.	287.0	103.0	57-----	9,680	975.1	C-119 C-130 C-123 C-124 C-133

Trailer: Dump, 7-8 cu. yd., For Tractor, Air Transport- able, Wheel Type, 7,800 to 14,000 lb., DBP, w/Weight Transfer Device.	M-R-S Model 75 AGW. 2805.227.0482.	318.0	96.0	90-----	10,400	1,590.0	C-119 C-130 C-123 C-124 C-133
Tractor, Saw, Power Unit, Wheelbarrow type, G.D. 3750.275.000.	Little Giant Model 22-4. 3750.275.000.	133.0	38.0	36-----	1,080	105.3	C-97 C-130 C-119 C-123 C-124 C-133 C-97 C-130
Spreader: Aggregate, Towed, Traction Powered, 8 ft. width.	Good Roads Machin- ery Co. Model 8. 3895.223.8210.	107.0	45.0	37-----	1,550	103.1	C-119 C-123 C-124 C-133 C-97 C-130
Tank: Water, Steel, Semi- Trailer, Mounted, 1,500 gal. 2330.271.9947.	Columbian Steel Tank Co. 2330.368.2818.	220.0	96.0	90-----	7,000	1,100.0	C-119 C-130 C-123 C-124 C-133 C-97 C-130
Pump: Water, Trailer Mounted w/Distributor Attachments. 3825.263.2975.	Rosco Model MAE. 3825.269.2976.	180.0	78.0	73-----	2,200	593.1	C-119 C-123 C-124 C-133 C-97 C-130
Pump: Water, Centrifugal, G.D., Trailer Mtd., 4 in. discharge, 4 in. suction, 500 GPM @ 20 ft. head, Normal discharge. 4320.289.3699.	Carver Model 4822. 4320.289.3699.	48.0	37.0	51-----	800	52.4	C-119 C-123 C-124 C-133 C-97 C-130
Truck: Bolster Body, 2½ ton, 6 by 6 with Front Mtd. Winch.	GMC Model CCKW- 353. 2320.287.4249.	268.0	87.0	96-----	11,400	1,295.3	C-97 C-130 C-119 C-123 C-124 C-133
Water Purification Equipment: Diatomite #3, Set #3, Port- able, 35 GPM.	4610.190.0300-----				3,800 (uncrated) 5,200 (for export)		(¹)

¹ 15 boxes, 3 chests, and 3 unboxed items will be carried as part of loads in trucks, rollers, etc.

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued

[illegible]

Bridge: Floating, Pneumatic
Float, Class 60, Steel Su-
perstructure. 5420-267-
0012.

Bridge: Fixed Steel Panel,
Bailey Type M-2. 5420-
530-3784. Erection Set.
5420-530-3785.

40	A	Floating Bay-----	224	98	68	16, 303	863. 9	C-119 C-130 C-123
2	B	Ramp Load A-----	224	98	66	17, 074	383. 1	C-124 C-133 C-119 C-130 C-123
2	C	Ramp Load B-----	195	98	65	16, 287	718. 3	C-124 C-133 C-119 C-130 C-123
2	D	Anchorage Load-----	176	98	37	10, 832	469. 1	C-124 C-133 C-119 C-130 C-123
2	F	Trestle-----	272	98	42	15, 817	647. 9	C-124 C-133 C-119 C-130 C-123
4	F	Miscellaneous-----	176	98	48	1, 669	479. 1	C-124 C-133 C-119 C-130 C-123
2	#1	Accessory-----	201	80	32	6, 024	297. 8	C-124 C-133 C-97 C-130 C-119 C-123
4	#2	Ramp-----	167	80	24	4, 939	185. 6	C-124 C-133 C-97 C-130 C-119 C-123
7	#3	Decking-----	167	80	26	6, 645	185. 6	C-124 C-133 C-97 C-130 C-119 C-123 C-124 C-133

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—Continued

[illegible]

Table 10. Dimensions, Weights, and Air Transportability of Engineer Equipment—
Continued

Item	Length (inches)	Width (inches)	Height (inches)	Weight (pounds)	Transporting air- craft	
Tractor, Crawler, Diesel, Air- borne D6-S. 2410-240-2738.	166	88	80	15, 500	C-97	C-130
					C-119	
					C-123	
					C-124	C-133
Traxcavator, Cat. Model 933...	166	70	76	15, 400	C-97	C-130
					C-119	
					C-123	
					C-124	C-133
Bucket, Clamshell, 3.4 yd. 3815-272-8674.	70	65	34	2, 400	C-97	C-130
					C-119	
					C-123	
					C-124	C-133
Bucket, Dragline, 3.4 yd. 3815-186-3571.	90	40	60	2, 100	C-97	C-130
					C-119	
					C-123	
					C-124	C-133
Grader, Road, Air Transport- able, Cat. 212. 3805-223- 9029.	264	79	101	14, 220	C-97	C-130
					C-119	
					C-123	
					C-124	C-133
Roller, Sheepsfoot, Airborne, Model TRO-112. 3895-351- 9805.	175	115	58	6, 040	C-97	C-130
					C-119	
					C-123	
					C-124	C-133
Scraper, Road, Towed, Ty., 12 cu. yd., Le Tourneau Model LPO. 3805-351-9542.	389	125	133	20, 175	C-124	C-133
Tank, Water, Skid. 5430-256- 6601.	96	52	48	760	C-97	C-130
					C-119	
					C-123	
					C-124	C-133

10. Ordnance Vehicles

The overall dimensions, volumes in measurement tons, and net weights of certain ordnance vehicles issued to engineer units are given in table 11.

Table 11. Ordnance Vehicles Issued to Engineer Troop Units

Vehicle	Dimensions (inches)			Measure- ment tons	Net weight, pounds
	Length	Width	Height		
Trailer, cargo, ¼-ton, 2-wheel-----	108½	56¼	42	3. 7	565
Trailer, amphibious cargo, ¼-ton, 2-wheel-----	108½	56	40	2. 9	550
Trailer, cargo, ¾-ton, 2-wheel (M101)-----	143¾	73½	83	4. 4	1, 340
Trailer, cargo, 1½-ton, 2-wheel (M104)-----	165½	83	¹ 99½	7. 1	2, 400
Trailer, water-tank, 1½-ton, 2- wheel (M106)-----	166¾	² 93	79¾	17. 5	2, 280
Truck, utility, ¼-ton, 4 by 4 (M38, Willys)-----	133	62	³ 74	6. 7	2, 625
Truck, pickup, ½-ton, 4 by 2 (Chevrolet)-----	197	75	76	16. 3	3, 330
Truck, cargo, ¾-ton, 4 by 4 (M37, Dodge)-----	189¾	73½	⁴ 89½	12. 6	5, 917
Truck, command, ¾-ton, 4 by 4 (M42)-----	184¾	73½	89¾	17. 4	6, 050
Truck, ambulance, ¾-ton, 4 by 4 (M43)-----	198¾	73½	91¾	19. 8	7, 150
Truck, stake and platform, 1½-ton, 4 by 2 (Chevrolet)-----	265	87½	88	29. 6	5, 675
Truck, cargo, 2½-ton, 6 by 6 LWB (GMC)-----	256¾	88	93	30. 4	10, 550
Truck, cargo, 2½-ton, 6 by 6, LWB, WW (GMC)-----	270¾	88	93	32. 0	11, 250
Truck, dump, 2½-ton, 6 by 6 (M47)-----	235½	85	104	30. 0	13, 540
Truck, gasoline tank, 2½-ton, 6 by 6, 750-gal (GMC)-----	253½	91	⁵ 93	31. 1	10, 750
Truck, gasoline-tank, 2½-ton, 6 by 4, 1,350-gal-----	288	92	95	36. 5	11, 100
Truck, shop van, 2½-ton, 6 by 6 (M535)-----	255½	96	⁶ 118	33. 5	10, 100
Truck, stake and platform, 2½- ton, 4 by 2 (International Har- vester)-----	276¾	92¼	91¼	33. 8	7, 110
Truck, water-tank, 2½-ton, 6 by 6, 700-gal (GMC)-----	253½	90	95	31. 5	11, 913
Truck, cargo, 5-ton, 6 by 6, LWB, WW (M41)-----	309¾	96	⁷ 118¾	47. 8	19, 835
Truck, dump, 5-ton, 6 by 6 (M51)---	266¾	97	⁸ 110¾	41. 5	21, 981

See footnotes at end of table.

Table 11. Ordnance Vehicles Issued to Engineer Troop Units—Continued

Vehicle	Dimensions (inches)			Measure- ment tons	Net weight, pounds
	Length	Width	Height		
Truck, dump, 5-ton, 6 by 6, WW (M51)-----	281 $\frac{5}{8}$	97	⁸ 110 $\frac{5}{8}$	43. 9	22, 664
Truck, medium wrecker, 5-ton, 6 by 6-----	309 $\frac{3}{4}$	97	102 $\frac{1}{2}$	61. 7	33, 675
Truck, tractor, 5-ton, 6 by 6, SWB, WW (M52)-----	273	97	⁹ 102	39. 5	18, 996
Truck, tractor, 12-ton, 6 by 6 (H26)-----	306	130 $\frac{1}{2}$	123	74. 0	48, 895
Vehicle, armored, tracked-----	214	113	77 $\frac{1}{2}$	28. 2	35, 500

¹ Can be collapsed to 58 inches.

² Retractable to 83 inches.

³ Reducible to 55 inches.

⁴ Reducible to 63 $\frac{1}{2}$ inches.

⁵ Reducible to 81 $\frac{1}{2}$ inches.

⁶ Collapsible to 94 inches.

⁷ Reducible to 88 inches.

⁸ Reducible to 87 $\frac{3}{4}$ inches without cab protector.

⁹ Reducible to 86 $\frac{1}{2}$ inches.

11. Vehicles Upon Which Smaller Vehicles Can Be Loaded.

Table 12. Loading Vehicles on Vehicles

Small vehicles	2 $\frac{1}{2}$ -ton 6 by 6 cargo (LWB)	2 $\frac{1}{2}$ -ton 6 by 6 cargo (SWB)	1 $\frac{1}{2}$ -ton 4 by 4 15-foot cargo	1 $\frac{1}{2}$ -ton 4 by 4 cargo truck
$\frac{1}{4}$ -ton 4 by 4 truck-----	Yes-----	Possible ¹ ---	Yes-----	Possible. ²
$\frac{1}{4}$ -ton 2-wheel cargo trailer.	Yes-----	Yes-----	Yes-----	Yes.
1-ton 2-wheel cargo trailer.	Yes-----	Possible ³ ---	Possible ⁴ ---	Possible. ⁵
1-ton 2-wheel 250-gallon tank trailer.	Yes-----	Possible ⁶ ---	Possible ⁷ ---	Possible. ⁷

¹ 24 $\frac{1}{2}$ -inch overhang. Point at which rear wheels of small vehicle rest on floor is only 3 or 4 inches from end of truck platform.

² 24 $\frac{1}{2}$ -inch and 25 $\frac{1}{4}$ -inch overhang. Point at which rear wheels of small vehicle rest on floor is only 1 to 2 inches from end of truck platform.

³ 3-foot 1 $\frac{1}{2}$ -inch overhang. Trailer drawbar must be racked.

⁴ Trailer is wider than truck body at point 2 or 3 inches higher than top of truck body side panel. Bow standards must be removed.

⁵ Same as note 4 except 4 to 5 inches higher. Also 3 feet 1 $\frac{1}{2}$ inches to 3 feet.

⁶ 2-foot 4 $\frac{1}{2}$ -inch overhang. Trailer drawbar must be racked.

⁷ Same as note 4 except 4 to 5 inches higher. Also 2-foot 4 $\frac{1}{2}$ -inch to 2-foot 6-inch overhang which requires that trailer drawbar be racked.

12. Fuels, Lubricants, Hydraulic Fluids, and Antifreeze for Engineer Equipment.

a. Fuels, lubricants, and hydraulic fluids are issued for engineer equipment, depending on ambient conditions, as indicated in table 13.

b. Two types of antifreeze are issued. Ethylene glycol is normally issued when temperatures from 32° F. to -25° F. are anticipated. This is mixed with the engine coolant in varying proportions. Arctic antifreeze is normally issued for anticipated temperatures under -25° F. Arctic antifreeze is premixed and does not permit addition of water.

c. In addition to these two antifreeze materials it is common practice to add denatured alcohol to engine and heater fuel tanks when subfreezing temperatures are encountered. It is normally added in a ratio of one quart of alcohol to 30-50 gallons of gasoline.

d. Special priming devices and fluids are required to assist in starting diesel engines at extremely low temperatures. The Chevron Model Discharger (SNL number 78-3200-600-400) and the priming fluid capsules (78-6827.500.500) are provided for this purpose.

e. In addition to the above it is necessary to provide special winterization to standard equipment for operations in extremely low temperatures. Items such as special fan belts, hose, engine preheaters, and personnel heaters are required.

Table 13. Stock Military Fuels, Lubricants, Hydraulic Fluids, and Antifreezes for Engineer Equipment

Product	Federal stock No.	Container size	Applicable temperature range					
			Above 32° F.		32° F. to -25° F.		-25° F. to -65° F.	
			Specification	Symbol	Specification	Symbol	Specification	Symbol
Fuel oil, diesel, regular.....	9140-286-5296	55 gal.	VV-F-800 (Federal).....	DF-2				
Fuel oil, diesel, winter grade.....	9140-286-5288	55 gal.			VV-F-800 (Federal).....	DF-1		
Fuel oil, diesel, arctic grade.....	9140-286-5284	55 gal.			VV-F-800 (Federal).....	DF-A	VV-F-800 (Federal).....	DF-A
Gasoline, auto, combat (general).....	9130-221-0680	55 gal.	MIL-G-3096, type I.....	91A				
Gasoline, auto, combat (low temp).....	9130-221-0685	55 gal.			MIL-G-3056A, type II.....	91C	MIL-G-3056A, type II.....	91C
Lubr. oil, int. comb. eng.....	9150-265-9435	5 gal.	MIL-L-2104A.....	OE30				
Lubr. oil, int. comb. eng., Subzero.....	9150-242-7603	5 gal.			MIL-O-10295A.....	OES	MIL-O-10295A.....	OES
Lubr. oil, gear, grade 90.....	9150-240-2251	15 gal.	MIL-L-2105.....	GO-90				
Lubr. oil, gear, grade 75.....	9150-240-2243	15 gal.			MIL-L-2105.....	GO-75		
Lubr. oil, gear, subzero.....	9150-257-5441	15 gal.			MIL-L-10324 (ORD).....	GOS	MIL-L-10324 (ORD).....	GOS
Greases:								
Aircraft and instrument (for sealed bearings).....	9150-261-8208	1 lb.	MIL-G-3278.....	GL	MIL-G-3278.....	GL	MIL-G-3278.....	GL
Automotive and artillery (for chassis elements).....	9150-190-0907	35 lb.	MIL-G-10924, Amd 3.....	GAA	MIL-G-10924, Amd 3.....	GAA	MIL-G-10924, Amd 3.....	GAA
Automotive (water pump).....	9150-235-5503	1 lb.	VV-G-632, type A, grade 4 (Federal). VV-F-451a (Federal).....	WP HB	VV-G-632, type A, grade 4 (Federal). VV-F-451a (Federal).....	WP HB	VV-G-632, type A, grade 4 (Federal). VV-F-451a (Federal).....	WP HB
Hydraulic fluid, non-petr. (brake system).....	9150-231-9071	1 gal.						
Hydraulic fluid, non-petr., arctic type (brake system).....	9150-252-6375	1 gal.					MIL-H-13910.....	HBA
Hydraulic fluid, petr. base.....	9150-223-4134	1 gal.	MIL-O-5606.....	OHA	MIL-O-5606.....	OHA	MIL-O-5606.....	OHA
Lubr. oil, instrument.....	9150-223-4129	1 qt.	MIL-L-6085.....	OAI	MIL-L-6085.....	OAI	MIL-L-6085.....	OAI
Antifreeze, ethylene-glycol type.....	6850-243-1992	55 gal.			O-E-771a (Federal).....			
Antifreeze, arctic type.....	6850-243-1991	55 gal.			MIL-C-11755.....	CA-A	MIL-C-11755.....	CA-A
Alcohol, denatured, gr III.....		1 gal.			O-A-396 (Federal).....		O-A-396 (Federal).....	

13. Fuel and Lubricant Consumption

Those vehicles or pieces of equipment marked with an asterisk show petroleum consumption based on "gallons per hour" (GPH); those vehicles or pieces of equipment marked with 2 asterisks show the petroleum consumption rate based on the movement of a unit for 50 miles. The factors influencing petroleum consumption are as follows:

a. Cross-country movement is estimated at two and one-half times the consumption over roads.

b. For arctic winter operations, increase all basic amounts by 25 percent.

c. To cover such items as spillage, evaporation, and small combat losses, an additional 10 percent of the total consumption figure should be included in the estimation.

d. An experienced vehicle or equipment operator will, as a general rule, use less petroleum products than an inexperienced person.

e. The newness and condition of the vehicles and equipment will have a bearing on the estimated amounts of petroleum products required, and should be considered.

f. The movement of vehicles and equipment within bivouac areas and on reconnaissance, the warming up of engines, and abnormal periods of low-gear operation must be considered when estimating petroleum requirements.

g. Additional daily requirements exist for administrative vehicles, gasoline-powered equipment, and maintenance and testing of engines.

Table 14. Fuel and Lubricant Consumption Rates of Engineer and Ordnance Equipment

Item	Gasoline	Diesel	Gallons OE	Gallons OO90	Pounds GAA
Auger, earth, trk, mtd.*-----	2.5	-----	.03	.03	.06
Cleaning unit, steam, shop, whl. mtd., oil burner.*-----	-----	1	-----	-----	-----
Compressor, air, 3 stages 15 CFM, GED.*-----	.6	-----	.02	-----	-----
Compressor, air, 210 CFM, trk. mtd.*-----	5	-----	.04	.03	.05
Compressor, air, piston and rotary types, 315 CFM.*-----	-----	4	.1	-----	.04
Conveyor, skd. mtd. 24 by 50 GED.*-----	2	-----	.04	.09	.06
Crane, ¾ cu. yd., trk. mtd.*-----	4.3	-----	.06	.03	.05
Crane, 20 ton, non-revolving.*-----	-----	-----	-----	-----	.03
Crane, 2 cu. yd., CLR.*-----	5.7	-----	.09	.09	.1
Crushing Plant, 3 unit, 50 ton per hour.*-----	2	5	5.8	.35	.25
Ditching machine, ladder type, 8 ft. depth.*-----	5	-----	.06	.09	.1

*Table 14. Fuel and Lubricant Consumption Rates of Engineer and
Ordnance Equipment—Continued*

Item	Gasoline	Diesel	Gallons OE	Gallons GO90	Pounds GAA
Distributor, bit., trk. mtd. 800 gal. cap.*-----	4. 1	-----	. 04	. 03	. 05
Distributor, water, trk. mtd., 1000 gal.*-----	4. 1	-----	. 04	. 03	. 05
Dolly, 4 wheel for 20 ton semi.*	-----	-----	-----	-----	. 03
Electric lighting equipment, set #4, 5 KW.*-----	3. 5	-----	-----	. 03	-----
Electric lighting equipment, set #5, trk. mtd., 15 KW.*-----	3	-----	. 05	-----	-----
Flood light equipment, set #2, GED.*-----	3. 5	-----	. 03	-----	-----
Grader, road motorized.*-----	-----	4	. 06	. 03	. 06
Heater, asphalt, tlr. mtd.*-----	. 6	2. 5	. 02	-----	. 02
Kettle, asphalt, tlr. mtd., 165 gal.*-----	. 6	2	. 02	-----	. 03
Loader bucket.*-----	8. 75	5	. 04	. 03	. 06
Lubricator, tlr. mtd.*-----	1	-----	. 02	-----	. 01
Mixer, concrete, tlr. mtd. 16 cu. ft.*-----	2	-----	. 03	-----	. 03
Mixer, rotary-tiller.*-----	2. 3	3. 8	. 09	. 06	. 06
Power unit, #162.*-----	. 6	-----	. 01	-----	-----
Pump, asphalt, tlr. mtd.*-----	2	-----	. 03	-----	. 03
Pump, diaphragm, push cart mtd.*-----	. 6	-----	. 02	-----	-----
Pump, centrifugal for gas, 3'' by 240 GPM @ 60 ft. head.*-----	. 8	-----	. 03	-----	-----
Quarry set #1, wagon drills.*-----	-----	-----	. 03	-----	. 03
Roller, road, 5-8 ton.*-----	2	-----	. 05	. 02	. 03
Roller, road, 3 wheel, 10 ton.*-----	2. 5	-----	. 03	. 03	. 03
Roller, road, towed type, 50 ton.*-----	-----	-----	-----	-----	. 03
Roller, road, towed type, 13 wheel.*-----	-----	-----	-----	-----	. 03
Roller, road, towed type, sheep- foot.*-----	-----	-----	-----	-----	. 03
Rooter, 3 tooth, H-3.*-----	-----	-----	-----	-----	. 03
Scraper, towed type, 8 cu. yd.*-----	-----	-----	-----	-----	. 04
Scraper, towed type, 12 cu. yd.*-----	-----	-----	-----	-----	. 05
Scraper, towed type, 18 cu. yd.*-----	-----	-----	-----	-----	. 06
Shop equipment, motorized GP.*-----	1. 6	-----	. 02	. 03	. 05
Shop equipment, motorized, heavy machine.*-----	1. 6	-----	. 02	. 03	. 05
Spreader, aggregate, towed type.*-----	-----	-----	. 03	-----	-----
Sweeper, 2-way, sweeping.*-----	-----	-----	. 03	-----	. 03
Tool set #3, emergency shop, 1½ KW gen., GED.*-----	. 6	-----	. 02	-----	-----

Table 14. Fuel and Lubricant Consumption Rates of Engineer and Ordnance Equipment—Continued

Item	Gasoline	Diesel	Gallons OE	Gallon GO90	Pounds GAA
Tractor, saw, wheelbarrow type.*-----	1	-----	.02	.02	.04
Tractor, wheel type, 3,000 to 3,700 DBP.*-----	3	-----	.03	.03	.05
Tractor, wheel type, 20,025 to 27,000 DBP.*-----	-----	6.3	.2	.06	.04
Tractor, D-6.*-----	.2	6	.1	.07	.05
Tractor, D-7.*-----	.2	6	.1	.07	.05
Tractor, D-8.*-----	.2	6	.1	.07	.05
Truck, utility, ¼ ton, 4 by 4.**	3	-----	.1	-----	.2
Truck, ¾ ton, 4 by 4.**-----	6	-----	.1	-----	.3
Truck, 1½ ton, 4 by 4.**-----	7	-----	.2	-----	.5
Truck, 1½ ton, 6 by 6.**-----	7	-----	.2	-----	.4
Truck, 2½ ton, 6 by 6.**-----	9	-----	.2	-----	.6
Truck, 4 ton, 6 by 6.**-----	17	-----	.3	-----	1
Truck, wrecker, 4 ton, 6 by 6.**	17	-----	.3	-----	1
Truck, dump, 5 ton.**-----	20	-----	1.3	.8	1.3
Truck, 5 ton, 6 by 6.**-----	17	-----	.4	-----	.9
Truck, med. wrecker, 5 ton, 6 by 6.**-----	19	-----	.4	-----	.5
Truck, prime mover, 6 ton, 6 by 6.**-----	25	-----	.5	-----	.9
Truck, hvy wrecker, 6 ton, 6 by 6.**-----	20	-----	.5	-----	.9
Truck, prime mover, 7½ ton, 6 by 6.**-----	20	-----	.5	-----	.9
Truck, crane.**-----	34	-----	.4	-----	.7
Truck, tractor, 5-6 ton (10-ton semitrailer).**-----	17	-----	.4	-----	.6
Truck, tractor, 12 ton.**-----	50	-----	.9	.3	1.3
Water, purification set #3, GED.**-----	5	-----	-----	.6	-----

14. Identification of Engineer Equipment Repair Parts

Manufacturers frequently stamp individual parts with a part number which furnishes a hint as to the part's identity. However, many parts bear stamped or casting numbers which are not the manufacturer's part number, and numerous manufacturers have parts which bear no number. Some manufacturers who use a parts-numbering system and a summary of their systems are shown in table 15.

a. The supply manuals in the 5-3-series contain identification and cross reference information for all Engineer repair parts which are assigned Federal Stock Numbers and are stocked in the CONUS Depot system.

b. Supply Manuals 5-3-1-1 through 5-3-1-6 contain the manufacturer's part and/or drawing number, the item noun, corresponding Federal Stock Number and former Engineer Stock number for the

item. The manufacturer's part and/or drawing numbers, which are arranged in alphabetical-numerical sequence in this series of manuals, will sometimes correspond with the manufacturer's stamped or casting number found on the part. This information would provide some assistance in the identification of Engineer repair parts where only the stamped or casting number is available.

Table 15. Engineer Equipment Repair Parts Identification

Manufacturer	Parts-numbering system
Allis-Chalmers Manufacturing Company (power units).	Six-digit numbers. Parts manufactured on subcontracts bear a 2- to 4-digit number, often that of the contractor, prefixed by the letter U.
Allis-Chalmers Manufacturing Company (tractors).	Five- to 7-digit numbers. Attachments have from 3- to 6-digit numbers prefixed or suffixed by various single letters.
Caterpillar Tractor Company-----	One digit followed by a single letter followed by a 4-digit number. Some few parts bear old numbers which are simply 5- or 6-digit numbers, or 4-digit numbers prefixed by the letters L or S.
Chrysler Corporation-----	Four- to 7-digit numbers.
International Harvester Company-	Four- or 5-digit numbers suffixed by the letters, D, DA, DAX, DX, DXA, or H.
R. G. LeTourneau, Incorporated.-	One- to 4-digit numbers prefixed by the letters C, D, E, F, H, L, or R.
P and H Company-----	Two-digit number followed by the letters H, K, N, P, or T, followed by a 3- or 4-digit number.
Wallace-Tiernan, Incorporated----	One- to 4-digit numbers prefixed by the letters P, U, R, CPC, CPU, CPW, CU, CUR, CUW, CUX, or WPP.
Wisconsin Company-----	One- to 4-digit numbers prefixed by a 2-letter symbol.

Section III. USAF AIRCRAFT AND AIRFIELD DATA

15. USAF Airfield and Aircraft Characteristics

The major types of theatre airfields, the critical types of USAF aircraft for each, and certain characteristics of these aircraft are given in table 16.

16. Airfield Requirements

a. Allowances used to determine the overall requirements for the logistical planning of airbase and airfield structures are given in table 17.

b. Labor and tonnage requirements for airfield construction and reconstruction are given in table 18.

c. Typical airfield construction quantities are given in table 19.

Table 16. USAF Airfield and Aircraft Characteristics

Airfield type	Aircraft type	Critical type USAF designation	Gross weight (pounds)	Maximum wheel load (pounds)	Maximum tire pressure (psi)	Overall dimensions (feet)					Takeoff ground run (feet) @ sea level and 59° F.
						Length	Wing span	Height	Tread		
									Main gear	Outer gear	
Forward cargo (short-time use).	Medium cargo.	C-119C	73,200-----	31,500-----	69.6-----	86. 5	109. 3	26. 5	32. 3	NA	2, 640
Forward cargo (extended use).	Heavy cargo--	C-124C	185,000-----	86,000-----	78.0-----	130. 0	174. 1	48. 3	37. 3	NA	5, 520
Forward tactical---	Fighter-----	F-101A	(¹)	(¹)	(¹)	67. 5	39. 8	18. 0	(¹)	NA	(¹)
Medium bomber---	Medium bombers.	B-47E	200,000-----	Rear assembly load 103,200.	Front 181.2; Rear 189.5.	107. 1	116. 0	28. 0	NA	44. 3	8, 050
Heavy bomber----	Heavy bomber.	B-52 B & D	Over 400,000--	Rear assembly load over 200,000.	(¹)	156. 5	185. 0	(¹)	NA	148. 4	(¹)

¹ Classified.

Table 17. Airbase and Airfield Allowances

Facility	Unit of measure	Construction standard					
		Field ¹		Intermediate ²		Temporary ³	
		Officers	Airmen	Officers	Airmen	Officers	Airmen
Space Allowances: Quarters.....	Square feet per person.....	80	40	80.0	40.0	80.0	40.0
Kitchen.....	Square feet per person.....	(4)	(4)	6.0	4.0	7.5	5.0
Dining facilities: Family style.....	Square feet per person.....	(4)	(4)	12.0	8.0	15.0	10.0
Cafeteria style.....	Square feet per person.....	(4)	(4)	6.0	4.0	7.5	5.0
Unit administration.....	Square feet per person.....	2	2	2.0	2.0	3.0	3.0
Unit supply.....	Square feet per person.....	2	2	2.0	2.0	3.0	3.0
Unit recreation and welfare.....	Square feet per person.....	6	4	6.0	4.0	9.0	6.0
Unit medical.....	Square feet per person.....	1	1	1.0	1.0	1.0	1.0
Sanitary Installations: Toilet seat and urinals.....	Persons per fixture.....	(4)	(4)	10.0	⁵ 20.0	10.0	⁵ 20.0
	Square feet per seat and urinal ⁶			25.0	25.0	25.0	25.0
Showers.....	Persons per head.....	(4)	(4)	10.0	20.0	10.0	20.0
	Square feet per head.....			50.0	50.0	50.0	50.0
Lavatory.....	Persons per fixture.....	(4)	(4)	5.0	10.0	5.0	10.0
	Square feet per fixture.....			15.0	15.0	15.0	15.0
Scrub deck or laundry.....	Square feet per person.....	(4)	(4)	2.0	2.0	2.0	2.0
Water Allowances: Kitchens.....	Gallons per person per day.....	(4)	(4)	5.0	5.0	5.0	5.0
Showers and lavatories.....	Gallons per person per day.....	(4)	(4)	20.0	20.0	20.0	20.0
Latrines.....	Gallons per person per day.....	(4)	(4)	0.0	0.0	10.0	10.0
Lighting Allowances: Quarters.....	Watts per square foot.....	(4)	(4)	0.4	0.4	0.4	0.4
Kitchens.....	Watts per square foot.....	(4)	(4)	0.6	0.6	0.6	0.6
Dining facilities.....	Watts per square foot.....	(4)	(4)	0.4	0.4	0.4	0.4

See footnotes at end of table.

Table 17. Airbase and Airfield Allowances—Continued

Facility	Unit of measure	Construction standard					
		Field ¹		Intermediate ²		Temporary ³	
		Officers	Airmen	Officers	Airmen	Officers	Airmen
Unit administration.....	Watts per square foot.....	(4)	(4)	1. 0	1. 0	1. 0	1. 0
Unit supply.....	Watts per square foot.....	(4)	(4)	0. 2	0. 2	0. 2	0. 2
Unit recreation and welfare.....	Watts per square foot.....	(4)	(4)	1. 2	1. 2	1. 2	1. 2
Showers.....	Watts per square foot.....	(4)	(4)	0. 3	0. 3	0. 3	0. 3
Lavatories.....	Watts per square foot.....	(4)	(4)	1. 6	1. 6	1. 6	1. 6
Toilet seats and urinals.....	Watts per square foot.....	(4)	(4)	0. 2	0. 2	0. 2	0. 2

¹ This is equivalent to OCE Construction Standard No. 2.² This is equivalent to OCE Construction Standard No. 4.³ This is equivalent to OCE Construction Standard No. 6.⁴ Not applicable.⁵ Reduce to 15 persons per fixture for WAF.⁶ For trough urinals, 2 feet of trough equals one urinal.

Table 18. Airfield Labor and Tonnage Requirements

New Construction ¹					
Airfield type and critical aircraft	Engineer battalion-months ²			Construction supplies ³	
	Stage I	Stage II	Stage III	Measurement tons	Short tons
Forward cargo, medium C-119C (one wing)-----	2.5	-----	-----	1,200	1,200
Forward cargo, heavy C-124C (one wing)-----	-----	11.0	15.0	3,000	3,000
Forward tactical F-101A (one wing)-----	6.0	9.0	13.0	9,000	9,000
Medium bomber B-47E (one wing)-----	11.0	16.0	27.0	35,000	24,000
Heavy bomber B-52 B and D (one wing)-----	12.0	18.0	30.0	50,000	35,000

¹ For rehabilitation of a site where an airfield exists or has existed use 75 percent of the above factors.

² Battalion-months are computed on the basis of 110,000 effective man-hours per month for one engineer construction battalion TOE 5-115D, full strength.

³ This figure will fluctuate due to site selection and construction material selection.

Table 19. Typical Airfield Construction Quantities

	Surfaced area (square yards)	Graded area (square yards)	Base course (cubic yards)	Asphalt (gallons)	Chips (cubic yards)	Stripping (cubic yards)	Excavation (cubic yards)	Fill (cubic yards)	Rock (cubic yards)	Culverts (feet) (diam- eter inches)
Runway (paved 10,000 ft. by 300 ft)-----	333, 300	769, 250	100, 000	249, 800	3, 320	92, 300	307, 700	246, 200	4, 350	-----
Runway (paved 6,500 ft. by 150 ft)-----	108, 300	250, 000	32, 500	81, 200	1, 080	30, 000	100, 000	80, 000	1, 350	-----
Main taxiway-----	41, 500	64, 200	12, 400	24, 900	420	7, 000	35, 000	29, 000	-----	200-36
Apron access taxiway-----	17, 700	28, 400	5, 300	10, 600	180	6, 000	30, 000	25, 000	-----	300-36
Hardstand area warmup apron, taxiway-----	14, 500	23, 200	4, 400	8, 700	150	-----	-----	-----	-----	-----
Circulation taxiways-----	3, 900	6, 200	1, 200	2, 300	40	1, 000	2, 000	2, 000	-----	-----
Main transport apron-----	72, 200	82, 300	21, 700	43, 300	720	17, 000	20, 000	17, 000	-----	-----
Service apron-----	17, 800	21, 200	5, 300	10, 700	180	7, 000	10, 000	8, 000	-----	210-36
Warmup apron-----	4, 400	5, 100	1, 300	2, 600	40	2, 000	5, 000	4, 000	-----	-----
Drum-fill area-----	9, 600	10, 000	1, 600	-----	-----	3, 000	6, 000	4, 000	-----	-----
Transport hardstands-----	5, 800	10, 000	1, 700	3, 500	60	-----	-----	-----	-----	-----
Roads-----	68, 000	111, 500	11, 300	-----	-----	4, 000	25, 000	20, 000	-----	200-18
Total ¹ -----	{ 363, 700	612, 100	98, 700	187, 800	2, 870	77, 000	233, 000	189, 000	1, 350	710-36 200-18

¹ With 6,500-ft. by 150-ft. runway.

17. Data on Hangars

Data on hangars are given in table 20.

18. Characteristics of Portable Airfield Surfacing

Characteristics of portable airfield surfacing are given in table 21.

Table 20. Hangars

Type building	Size (feet)	Short tons	Measurement tons
Butler type CH, canvas roof and doors...	130 by 160	75.0	112.0
Butler combat hangar, type CHS, steel and canvas doors.	130 by 160	95.0	135.0
Butler combat hangar, type CHS, with steel sliding doors.	130 by 160	110.0	145.0
Luria catenary tent	130 by 160	33.0	64.0
Luria catenary tent	130 by 96	22.0	43.0
OCE design:			
3-hinged arch, TO 12, 17 metal-sheathed canvas doors.	130 by 160	98.0	85.0
2-hinged arch, TO 12, 19 all steel	160 by 190	198.0	125.0
Shed type hangar (55 feet by multiples of 32 feet, TO 12, 124): Per basic unit.	32 by 55	19.0	23.0
Per extension unit	32 by 55	10.3	14.5

Table 21. Characteristics of Portable Airfield Surfacing

Type	PSP (10 ga)	M-6 (10 ga)	M-8 (10 ga)	PAP (3/16")	M-9 (3/16")
Unit weight and dimensions:					
Weight (pounds per square foot) -----	5.1 -----	5.4 -----	7.3 -----	2.54 -----	3.7 -----
Length -----	10'0" -----	10'0" -----	11'9 3/4" -----	10'0" -----	11'9 3/4" -----
Width -----	1'3" -----	1'3" -----	1'7 1/2" -----	1'3" -----	1'10 1/4" -----
Depth -----	7/8" -----	7/8" -----	1'1/8" -----	1" -----	1 1/2" -----
Placing area—1 panel (square feet) -----	12.5 -----	12.5 -----	19.2 -----	12.5 -----	21.8 -----
Bundles:					
Number of units -----	30 planks ¹ -----	30 planks ¹ -----	14 planks -----	30 planks -----	14 planks -----
Square feet placing in 1 bundle -----	375 -----	375 -----	268.8 -----	375 -----	305.2 -----
Gross weight per bundle (pounds) -----	1,928 -----	2,055 -----	1,960 -----	975 -----	1,120 -----
Bundle dimensions, width, length, height -----	1'4 1/2" by 10'0" by 1'2" -----	1'4 1/2" by 10'-1 3/4" by 1'2" -----	1'10 1/2" by 12'1" by 1'0" -----	1'5" by 10'0" by 1'3" -----	2'3" by 12'1" by 1'3 3/4" -----
Volume—1 bundle (cubic feet) -----	16.0 -----	16.3 -----	22.7 -----	17.7 -----	35.6 -----
Requirements for 5,000 by 150' runway:					
Quantity (bundles or rolls) -----	2,000 -----	2,000 -----	2,790 -----	2,000 -----	2,450 -----
Weight (tons) -----	1,928 -----	2,055 -----	2,734 -----	975 -----	1,376 -----
Cargo space (cubic feet) -----	32,084 -----	32,552 -----	63,333 -----	35,418 -----	87,505 -----
Ship tons (40 cubic feet equals 1 ship ton) -----	802.10 -----	813.80 -----	1,583.25 -----	885.45 -----	2,188 -----
Cargo density (pounds per cubic feet gross weight) -----	120.18 -----	126.26 -----	86.34 -----	55.06 -----	31.46 -----
Area covered per cubic feet cargo space -----	23.376 -----	23.040 -----	11.8415 -----	21.176 -----	8,573 -----
Average laying speed (square feet per man-hour) -----	125 -----	60-75 ² -----	150 ² -----	150 -----	175 ² -----

¹ Breaks down into 6 subbundles of 5 each. 1 subbundle contains 2 half panels and 4 full panels. Each bundle of M-6 contains end connectors. Each bundle of PSP contains clips.

² Estimated—based on limited information.

Section IV. U.S. ARMY AIRCRAFT AND AIRFIELD DATA

19. Army Aircraft Characteristics

The major types of Army aircraft and certain of their characteristics are given in table 22.

20. Army Airfield Design Criteria

Design criteria for Army airfields are given in table 23. For flightway and flightstrip nomenclature, see figures 1 and 2.

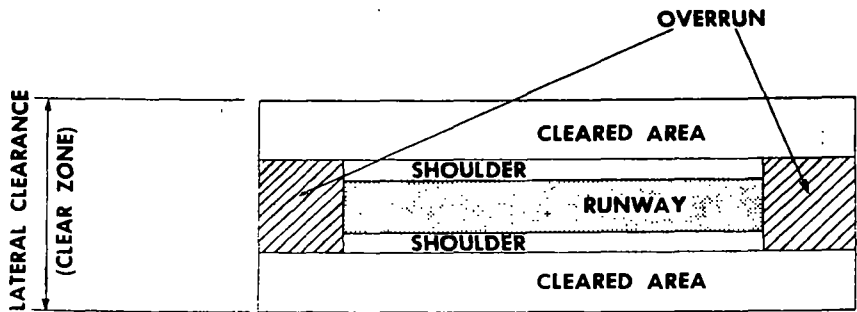


Figure 1. Flightstrip nomenclature.

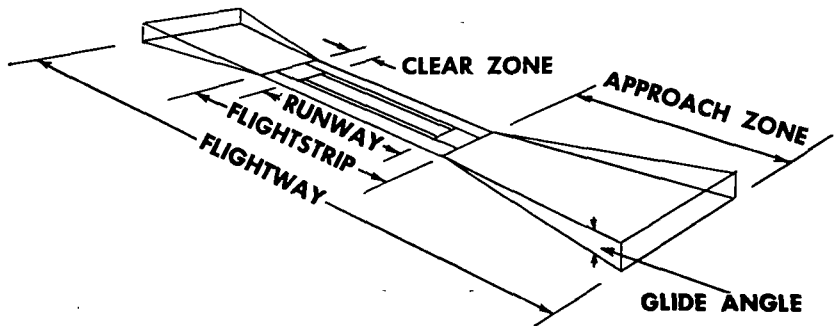


Figure 2. Flightway nomenclature.

21. Army Heliport Design Criteria

Army heliport design criteria are given in table 24.

Table 22. Army Aircraft Characteristics

FIXED-WING AIRCRAFT (AIRPLANES)

Aircraft type	Army designation	Gross weight (pounds)	Maximum wheel load (pounds)	Tire pressure (pounds per square inch)	Overall dimensions				Takeoff ground run (TGR): sea level, 59° F.
					Length	Wingspan	Height	Tread	
Observation.....	L-19 (Bird Dog).....	2, 400	1, 150	22	22' 0"	36' 0"	9' 2"	7' 5"	421
Utility.....	L-20 (Beaver).....	4, 820	2, 350	25	30' 4"	48' 0"	10' 5"	10' 2"	481
Light transport.....	U-1 (Otter).....	7, 600	2, 850	28	41' 10"	58' 0"	12' 7"	11' 2"	550
Command.....	L-23.....	6, 000	2, 700	35	31' 6"	45' 5"	11' 4"	12' 10"	1, 000

ROTARY-WING AIRCRAFT (HELICOPTERS)

Aircraft type	Army designation	Gross weight (pounds)	Maximum wheel load (pounds)	Tire pressure (pounds per square inch)	Overall dimensions			
					Length	Rotor diameter	Height	Tread
Reconnaissance.....	H-13.....	2, 350	1, 170	Skid.....	41' 5"	35' 2"	9' 6"	7' 6"
	H-23.....	2, 570	1, 285	Skid.....	40' 6"	35' 0"	9' 9"	7' 6"
Utility.....	H-19.....	8, 100	2, 700	35.....	62' 5"	53' 0"	14' 5"	11' 0"
	H-40.....	5, 200	2, 600	Skid.....	48' 9"	44' 0"	14' 7"	7' 10¼"
Cargo.....	H-21 (Light).....	11, 520	3, 840	115.....	86' 4"	44' 0"	16' 0"	13' 4"
	H-34 (Light).....	13, 300	5, 892	55.....	65' 10"	56' 0"	15' 10"	12' 0"
	H-37 (Medium).....	30, 900	13, 745	75.....	82' 10"	68' 0"	21' 6"	19' 9"

Table 23. Army Airfield Design Criteria

	Pioneer ¹	Hasty	Deliberate
RUNWAY			
1 Length (to nearest 100 ft.); corrected takeoff ground run multiplied by (safety factor).	1.10-----	1.50-----	1.75.
2 Width (minimum)-----	50 ft. sod or unpaved or 25 ft. shoulder-to- shoulder gravel or better road; open field.	50 ft.-----	75 ft.
3 Shoulder width (minimum)-----	0 ft.-----	10 ft.-----	10 ft.
4 Lateral clearance (width) of flightstrip-----	150 ft.-----	200 ft.-----	300 ft.
5 Runway surfacing-----	In-place sod or com- pacted base course.	Portable-----	Rigid or flexible pave- ment.
6 Longitudinal grade (maximum)-----	10 percent-----	5 percent-----	3 percent.
7 Maximum rate of change in grade per 100 ft. on vertical curves.	1.0 percent-----	0.5 percent-----	0.333 percent.
8 Minimum sight distance across vertical curves (height of eye 5', to a point 5' above run- way surface).	½ runway length-----	500 ft. plus ½ runway length.	500 ft. plus ½ runway length.
9 Minimum distance PI to PI on vertical curves-----	200 ft.-----	600 ft.-----	800 ft.
10 Transverse slope (minimum)-----	Natural surface-----	1.5 percent-----	1.5 percent.
11 Transverse slope (maximum)-----	5 percent-----	3.0 percent-----	3.0 percent.
12 Transverse shoulder slope (minimum)-----	NA-----	½ percent greater than runway transverse slope.	½ percent greater than runway transverse slope.
13 Transverse shoulder slope (maximum)-----	NA-----	5.0 percent-----	5.0 percent.
14 Parallel runways (minimum spacing, center to center).	200 ft.-----	300 ft.-----	300 ft.
15 Cleared areas, maximum slope----- See footnote at end of table	Unlimited-----	10 percent-----	10 percent.

Table 23. Army Airfield Design Criteria—Continued

	Pioneer ¹	Hasty	Deliberate
TAXIWAYS			
16 Width (to nearest 10 ft.)-----	NA-----	20 ft.-----	20 ft.
Landing gear tread multiplied by — but not less than—.	NA-----	1.5-----	1.75
17 Shoulder width (minimum)-----	NA-----	5 ft.-----	5 ft.
18 Lateral clearance, taxiway width plus —	NA-----	Airplane wingspan-----	Airplane wingspan.
19 Longitudinal grade (maximum)-----	NA-----	6 percent-----	6 percent.
20 Transverse slope (minimum)-----	NA-----	1.5 percent-----	1.5 percent.
21 Transverse slope (maximum)-----	NA-----	4 percent-----	3.0 percent.
22 Transverse shoulder slope (minimum)-----	NA-----	0.5 percent greater than taxiway transverse.	0.5 percent greater than taxiway transverse.
23 Transverse shoulder slope (maximum)-----	NA-----	5 percent-----	5 percent.
24 Taxiway horizontal curves except at intersections, minimum radius.	NA-----	75 ft.-----	100 ft.
HARDSTANDS AND APRONS			
25 Fillets of junction, minimum radius-----	NA-----	0 ft.-----	10 ft.
26 Diameter (minimum) or minimum dimension of square or rectangle.	NA-----	30 ft.-----	30 ft.
27 Width of hardstand where camouflage is required if manpower is used to move aircraft from taxiway.	NA-----	Airplane tread plus 5 ft.	Airplane tread plus 5 ft.
28 Shoulder width-----	NA-----	0 ft.-----	5 ft.
29 Minimum spacing, hardstands (center to center).	NA-----	100 ft.-----	100 ft.

30	Lateral clearance.....	NA.....	Hardstand or apron width plus wingspan.	Hardstand or apron width plus wingspan.
31	Slopes (any direction) (minimum).....	NA.....	1.5 percent.....	1.5 percent.
32	Slopes (any direction) (maximum).....	NA.....	5 percent.....	5 percent.
33	Area required for apron or minimum dispersal parking area. Number of airplanes $\times$ wingspan $\times$ length $\times$ factor.	1.0.....	1.5.....	2.0.
OVERRUN				
34	Length (from end of runway).....	NA.....	300 ft.....	500 ft.
35	Width (at runway end).....	NA.....	Width of runway plus two shoulder widths.	Width of runway plus two shoulder widths.
36	Grades, longitudinal (maximum).....	NA.....	10 percent.....	7 percent.
37	Slopes, transverse (maximum).....	NA.....	Same as runway and shoulders.	Same as runway and shoulders.
APPROACH ZONE				
38	Length (from end of flight strip).....	500 ft.....	1,500 ft.....	2,500 ft.
39	Width (at flight-strip end).....	Lateral clearance of flight strip.	Lateral clearance of flight strip.	Lateral clearance of flight strip.
40	Width, approximate (outer end).....	200 ft.....	750 ft.....	1,250 ft.
41	Glide angle ratios from end of flight strip:			
	Airfield for day use only.....	20.1.....	20.1.....	20.1.
	Airfield for day and night use.....	30.1.....	30.1.....	30.1.
	Airfield with instrument landing facilities.....	50.1.....	50.1.....	50.1.

Note. In the design of Army airfields and heliports or operation of Army aircraft at these locations, there shall be a minimum of 15 ft. clearance between the pavement edge nearest the runway end or edge and the lower surface of the flight approach zone. For coordination with public highway officials in matters pertaining to airway-highway clearance requirements, refer to SR 55-80-1.

¹ The criteria described under the heading "Pioneer" do not preclude the unit army aviation officer from selecting and using an airfield site from which he feels he can operate safely, and yet does not meet the minimum criteria described in table II. "All over" fields as distinguished from runways are acceptable and desirable since they provide increased area for operation and permit greater use in wet weather because of their ability to distribute traffic.

Table 24. Army Heliport Design Criteria

	Pioneer ¹	Hasty	Deliberate
RUNWAYS (LANDING AREA AND TAKEOFF AREA)			
1 Length, recommended minimum (dependent on type of helicopter and site conditions).	100 feet.....	300 feet.....	450 feet.
2 Width.....	25 feet.....	25 feet.....	40 feet.
3 Landing surfaces.....	In-place sod or compacted base course.	In-place sod or dust-free portable surface.	Flexible or rigid pavement.
4 Lateral clearance (min.).....	100 feet.....	150 feet.....	250 feet.
5 Grade, in any direction (max.).....	8.0 percent.....	4.0 percent.....	3.0 percent.
6 Transverse slope (min.).....	0 percent.....	1.5 percent.....	1.5 percent.
7 Shoulder width.....	0 feet.....	10 feet.....	10 feet.
8 Overrun width.....	None.....	Same as runway width plus two shoulders.	Same as runway width plus two shoulders.
9 Overrun length.....	None.....	50 feet.....	100 feet.
10 Shoulder and overrun, grade (max.).....	None.....	None.....	3.5 percent.
11 Parallel or adjacent runways (min.) center-to-center spacing.	200 feet.....	200 feet.....	300 feet.
12 Cleared areas, max. slope.....	+ 10 percent.....	+ 10 percent.....	+ 10 percent.
TAXIWAYS			
13 Width.....	None.....	20 feet.....	30 feet.
14 Longitudinal grade (max.).....	None.....	3.0 percent.....	2.0 percent.
15 Transverse slope (max.).....	None.....	3.0 percent.....	3.0 percent.
16 Shoulder width.....	NA.....	35 feet.....	35 feet.
17 Shoulder slope (max.).....	None.....	3.5 percent.....	3.5 percent.
18 Lateral clearance.....	None.....	90 feet.....	100 feet.

HARDSTANDS AND APRONS

19	Diameter, circular hardstands, or minimum dimension square or rectangular hardstands.	None-----	30 feet-----	40 feet.
20	Slope, any direction (max.)-----	None-----	3.0 percent-----	2.0 percent.
21	Slope, any direction (min.)-----	None-----	1.0 percent-----	0.5 percent.
22	Shoulder width-----	NA-----	30 feet-----	30 feet.
23	Shoulder slope (max.)-----	None-----	3.5 percent-----	3.5 percent.
24	Shoulder slope (min.)-----	None-----	½ percent greater than hardstand slope.	½ percent greater than hardstand slope.
25	Lateral clearance-----	None-----	90 feet-----	100 feet.
26	Spacing, hardstands, center-to-center (min.)-----	None-----	110 feet-----	125 feet.
27	Apron or minimum parking area: Number of helicopters×bladespan×overall length×factor.	1.0-----	1.5-----	2.0.

Section V. RAILROAD DATA

22. General

Responsibilities regarding railroads are covered in AR 55-650. Railroad bridges are covered in the TM 5-370-series; railroad surveys in the TM 5-235-series. Details of railroad engineering practice are given in various handbooks in engineer unit libraries. Railway gages and mileages of the world are given in paragraph 28.

23. Rail Shipments of Engineer Equipment

a. General. Large items of engineer motorized and other heavy construction equipment, when shipped by rail assembled or partially assembled and uncrated, are normally loaded lengthwise onto flatcars or drop-end gondolas. For dimensions of such equipment, see paragraphs 10 and 11. For dimensions of standard American railway cars, see FM 55-15.

b. Number of Items Per Car. To find what fraction of a car the item will occupy, divide the length of the car into the length of the item, plus a small allowance for clearance.

c. Loading on Flatcars.

- (1) For American mainline railroads and for a flatcar whose deck is 3 feet 6 inches above the top of the rail (the most common height), the following are the maximum permissible widths, at various heights, of any item loaded on the car:

<i>At a height, above car floor, of—</i>		<i>Maximum permissible width</i>
0 feet (car floor)	-----	10 feet 8 inches
10 feet 3 inches	-----	10 feet 8 inches
10 feet 9 inches	-----	10 feet 0 inches
11 feet 7 inches	-----	7 feet 0 inches

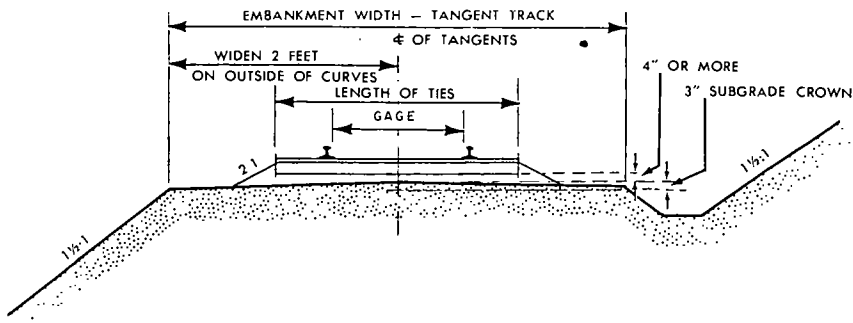
If the car deck is higher than 3 feet 6 inches, figures in the first column must be reduced by the amount in excess of 3 feet 6 inches.

- (2) For shipments on branch lines, somewhat lesser maximum heights and widths may have to be used. Clearance diagrams should be consulted before loading equipment.

d. Loading on Gondolas. Information in *c* above applies, with the qualification that, from the level of the car deck up to the top of the sides, the maximum permissible width of a loaded item is 6 inches less than the clear inside width of the car. This latter is usually 9 feet 0 inches to 9 feet 5 inches, though in some cases it may be as much as 10 feet 0 inches.

24. Tie Lengths and Embankment Widths

Tie lengths and embankment widths for single-track lines of various gages are shown in figure 3. Embankment widths and other elements of double-track lines, standard gage, are shown in figure 4. The 13-foot track spacing, center to center, is satisfactory for tangent track and is normally the minimum spacing used in multitrack layouts



GAGE FT. INS.	LENGTH OF TIES FT. INS.	EMBAKMENT WIDTH TANGENT TRACK FT. INS.
2'-6" OR LESS	7'-0"	15'-0"
3'-0"		
3'-3"		
3'-3 3/4" (METER)		
3'-5 1/2"	7'-6"	15'-0"
3'-6"		
4'-8 1/2" (STANDARD)		
5'-0"	8'-6" TO 9'-0"	16'-0"
5'-3"		
5'-6"		
	9'-6" TO 10'-0"	18'-0"

Figure 3. Cross section, single track.

for both yard and running tracks. In curved track, it is satisfactory for slow traffic only, and the spacing is normally increased to 14 feet or more in running tracks to allow for overhang of equipment, rocking of ears, and inequalities of superelevation.

25. Spacing of Parallel Tracks

Body tracks in yards are normally spaced a minimum of 13 feet on centers, except that the first body track is 15 feet on centers from a running track; and ladder tracks are at least 15 feet on centers from any parallel track. Tracks in pairs for operation of locomotive cranes are spaced at least 18 feet on centers.

26. Clearances

Overhead clearances and platform heights are measured from the top of the rail; side clearances from the centerline of track. Clearances below those specified are dangerous and require protection by appropriate warning signs or devices including telltales for overhead clearances between 22 feet and a minimum allowable of 18 feet. Unless local conditions require greater clearances, standard minimum clearances are as follows:

a. Overhead. High-voltage wires, 28 feet; other wires, 27 feet; overhead structures, 22 feet.

b. Side. The following side clearances are the absolute minimum distances. Where any side distance is less than 8 feet 6 inches, it should be posted along the appropriate line and on clearance diagrams.

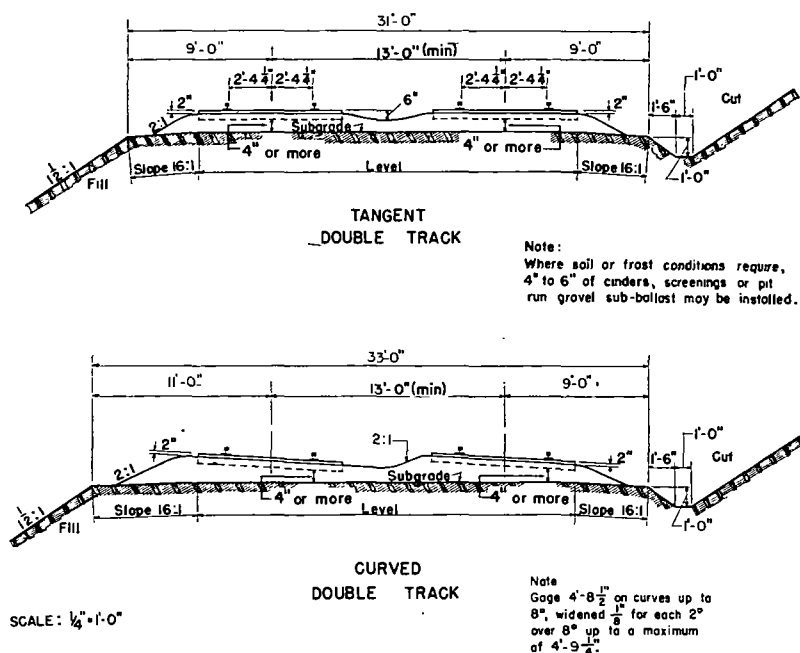


Figure 4. Cross section, double track.

- (1) Canopies up to 15 feet 6 inches high, 8 feet 6 inches.
 - (2) Canopies higher than 15 feet 6 inches, 5 feet 6 inches.
 - (3) Buildings, 8 feet 6 inches.
 - (4) Platforms 3 feet 9 inches high, 6 feet 2 inches.
 - (5) Refrigerator platforms 3 feet 2 inches high, 6 feet 2 inches.
 - (6) Refrigerator platforms 4 feet 7 inches high, 8 feet 6 inches.
 - (7) Low platforms 4 inches high, 5 feet 0 inches.
- c. *Enginehouse Entrances.*
- (1) Overhead, 17 feet 0 inches.
 - (2) Side, 6 feet 6 inches.

d. *Bridges and Tunnels.* Standard single-track bridge and tunnel clearances are shown in figure 5.

27. Materials for Standard-Gage Track

a. *Rail.* The new and used rail and accessories in the Department of the Army Supply Manual, SM 5-5, is the 75-pound-per-yard ASCE section, but this when depleted will be replaced by the 85-pound ASCE section in 39-foot lengths.

b. *Ties.* Ties listed in SM 5-5 are 6 by 8 inches, 8 feet long, for untreated cross-ties; and 7 by 9 inches, 8 feet long, for creosoted cross-ties, until depleted. Thereafter, the standard width of issue will be 8 feet 6 inches. Ties are produced locally if possible and may be creosoted if it is necessary to produce them in the United States for shipment overseas. Switch ties are listed in the same sizes by plan lengths,

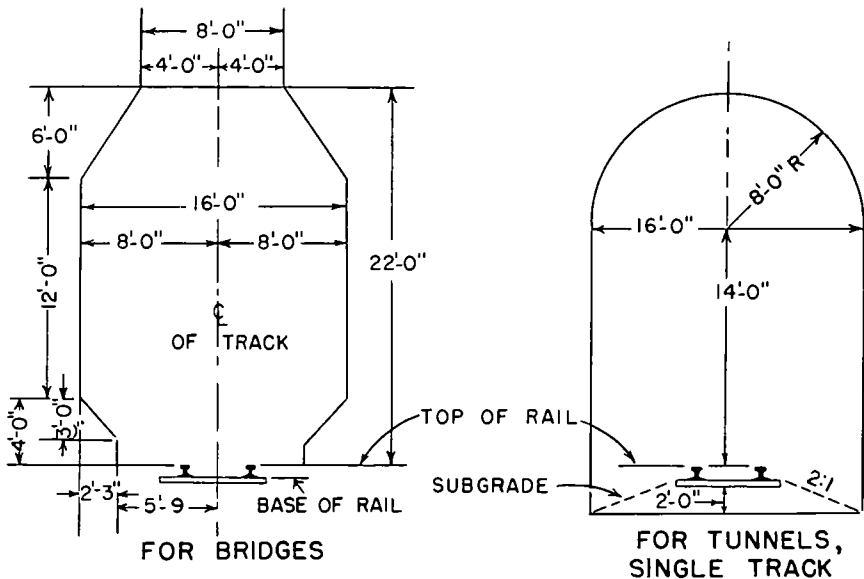


Figure 5. Standard single-track bridge and tunnel clearances.

in sets for number 8 turnouts. The engineering manual for Department of the Army construction provides minimum sizes of 7 by 9 inches for switch ties and 8 by 8 inches, 10 feet long, for bridge ties. Standard spacing is 19 and 21 ties per 39-foot rail for yard and running tracks, respectively.

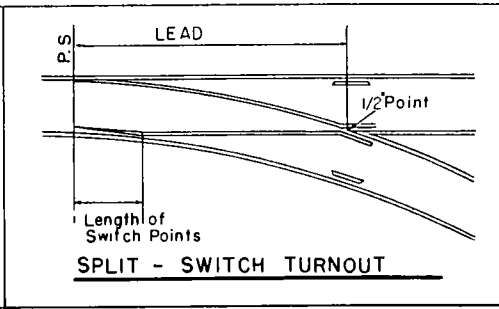
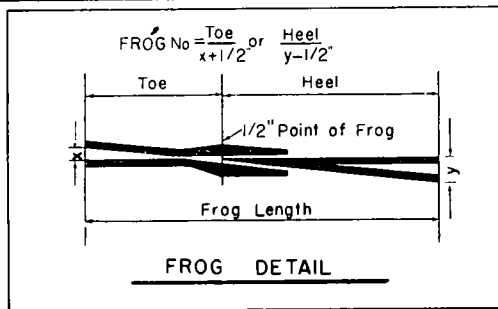
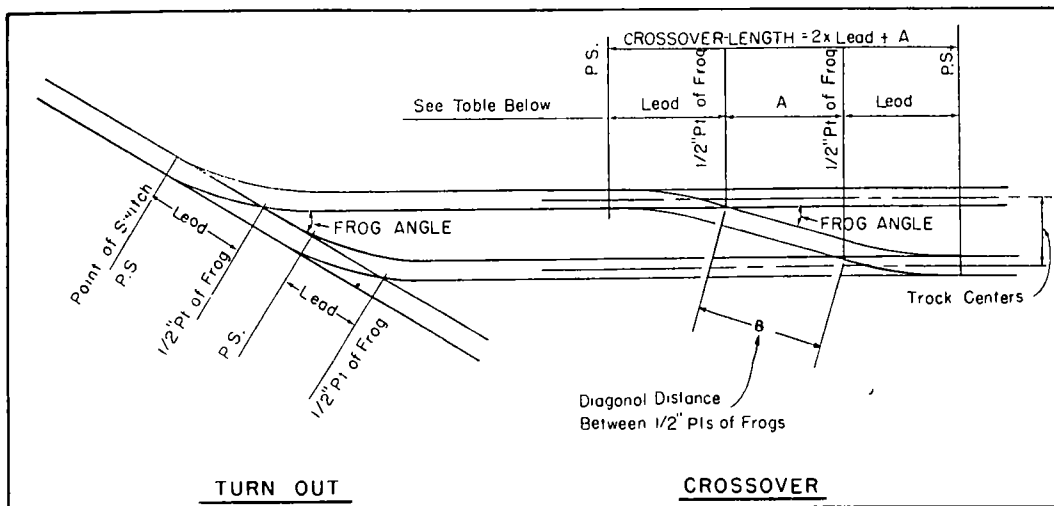
c. Tie Plates, Spikes, and Bolts. Steel tie plates, 9 by 6 by $\frac{3}{8}$ inches in size, are authorized for all track but may be omitted in hasty construction except at turnouts and sharp curves. Spikes are issued in the $\frac{5}{16}$ - by $5\frac{1}{2}$ -inch size, and track bolts in $\frac{7}{8}$ - by 4-inch and $\frac{7}{8}$ - by $4\frac{1}{2}$ -inch sizes.

d. Ballast. Crushed rock, slag, or gravel, in sizes graded from 3-inch to number 10 sieve, is best. Coarse cinder ballast is satisfactory for yard tracks and sidings and is brought to the tops of the ties to provide good footing for operating personnel. The engineering manual specifies a minimum depth of 8 inches under the ties, but as little as 4 inches can be used in hasty construction. The top of the ballast should clear the bottom of the rails by at least 1 inch. Ballast is produced locally wherever possible.

e Turnouts. The standard turnout is issued unassembled and is complete with low-stand throw and rigid-bolted number 8 frog. Dimensions and layout information for turnouts and crossovers using various frogs from number 6 to number 18 are given in figure 6.

28. Foreign Railroad Gages and Mileages

Standard gage, 4 feet $8\frac{1}{2}$ inches ($56\frac{1}{2}$ inches), is in general use in the United States. Table 25 gives the latest available information on foreign gages.



DIMENSIONS OF FROGS, SWITCHES, TURNOUTS AND CROSSOVERS												
FROG NO.	FROGS		SWITCHES		LEAD CURVE		TURNOUTS AND CROSSOVERS					
	FROG ANGLE	FROG LENGTH	LENGTH OF SWITCH POINTS	LEAD DISTANCE FROM PT. OF SWITCH TO 1/2" PT. OF FROG	RADIUS OF ft	DEGREE OF CURVE (deg)	DISTANCE IN FEET BETWEEN CENTER LINES OF TRACKS—GAGE—4'-8 1/2"					
							13'-0"		14'-0"		ft	
							A	B	A	B		
6	9°31'38"	10'-0"	11'-0"	47'-6"	258.57	22°17'58"	20'-5 1/2"	21'-6 1/2"	26'-5"	27'-7"	5'-11 1/2"	6'-0 1/2"
7	8°10'16"	12'-0"	16'-6"	62'-1"	365.59	15°43'16"	24'-0 3/8"	24'-11 5/8"	30'-11 15/16"	32'-0 1/16"	6'-11 9/16"	7'-0 7/16"
8	7°09'10"	13'-0"	16'-6"	68'-0"	487.28	11°46'44"	27'-7 1/8"	28'-4 7/8"	35'-6 3/4"	36'-5 1/4"	7'-11 5/8"	8'-0 3/8"
9	6°21'35"	16'-0"	16'-6"	72'-3 1/2"	615.12	9°19'30"	31'-1 5/8"	31'-10 3/8"	40'-1 5/16"	40'-10 11/16"	8'-11 11/16"	9'-0 5/16"
10	5°43'29"	16'-6"	16'-6"	78'-9"	779.39	7°21'24"	34'-8 1/8"	35'-3 7/8"	44'-7 13/16"	45'-4 3/16"	9'-11 11/16"	10'-0 5/16"
12	4°46'19"	20'-4"	22'-0"	96'-8"	1104.63	5°11'20"	41'-8 3/4"	42'-3 1/4"	53'-8 1/2"	54'-3 1/2"	11'-11 3/4"	12'-0 1/4"
14	4°05'27"	23'-7"	22'-0"	107'-0 3/4"	1581.20	3°37'28"	48'-9 1/4"	49'-2 13/16"	62'-9 1/16"	63'-3 1/16"	13'-11 13/16"	14'-0 1/4"
16	3°34'47"	26'-0"	30'-0"	131'-4"	2007.12	2°51'18"	55'-9 5/8"	56'-2 1/2"	71'-9 7/16"	72'-2 11/16"	15'-11 13/16"	16'-0 3/16"
18	3°10'56"	29'-3"	30'-0"	140'-11 1/2"	2578.79	2°13'20"	62'-9 7/8"	63'-2 3/16"	80'-9 11/16"	81'-2 3/8"	17'-11 13/16"	18'-0 3/16"
$\frac{1}{2}$ /COLUMNS A & B UNDER Q GIVE THE AMOUNTS TO ADD TO TABULAR FIGURES FOR EVERY ONE (1) FOOT INCREASE IN DISTANCE BETWEEN TRACKS												

Figure 6. Frogs and switches in turnouts and crossovers.

Table 25. Foreign Railroad Gages and Mileages

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Europe:				
Albania.....	56½	1. 434	79	126
	24	. 609	19	30
Austria.....	56½	1. 434	3, 440	5, 507
	39¾	1. 000	10	16
	29⅞	. 760	305	488
Belgium.....	56½	1. 434	3, 168	5, 068
	39¾	1. 000	2, 513	4, 020
Bulgaria.....	56½	1. 434	2, 420	3, 872
	30	. 762	186	297
	23½	. 600	95	152
Czechoslovakia.....	60	1. 524	5	8
	56½	1. 434	8, 000	12, 800
	39¾	1. 000	105	168
	29½	. 750		
Denmark.....	56½	1. 434	2, 885	4, 616
	39¾	1. 000	42	67
Finland.....	60	1. 524	3, 022	4, 835
	56½	1. 434	3	5
France.....	56½	1. 434	25, 151	40, 241
	39¾	1. 000	549	878
Germany:				
West.....	56½	1. 434	18, 811	30, 097
	39¾	1. 000	144	230
	29½	. 760		
East.....	56½	1. 434	8, 450	13, 520
	39¾	1. 000	650	1, 040
	29½	. 750		
Great Britain.....	56½	1. 434	19, 276	30, 841
	36	. 914	32	51
Greece.....	56½	1. 434	900	1, 440
	39¾	1. 000	660	1, 056
	23¾	. 600		
Hungary.....	56½	1. 434	4, 950	7, 920
	29½	. 760	210	336
Eire.....	63	1. 600	1, 892	3, 027
	36	. 914	136	217
Italy.....	56½	1. 434	11, 424	18, 278
	42¼	1. 067	2, 090	3, 344
	39¾	1. 000		
	37¾	. 950		
	29½	. 750		
Luxembourg.....	56½	1. 434	249	398
	39¾	1. 000	89	142
Netherlands.....	56½	1. 434	1, 979	3, 166
Norway.....	56½	1. 434	2, 691	4, 305
	42	1. 067	112	179
	39¾	1. 000		
	30	. 762		

Table 25. Foreign Railroad Gages and Mileages—Continued

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Poland-----	60	1. 524	30	48
	56½	1. 434	13, 500	21, 600
	39¾	1. 000	350	560
	30	. 762	151	241
	29½	. 750	608	972
	23⅝	. 600	768	1, 228
Portugal-----	66	1. 524	1, 759	2, 814
	39¾	1. 000	477	763
Rumania-----	60	1. 524	50	80
	56½	1. 524	5, 900	9, 440
	39¾	1. 000	430	688
	29½	. 750		
Saar-----	56½	1. 434	343	548
Spain-----	66	1. 677	8, 048	12, 876
	56½	1. 434	2, 997	4, 795
	48	1. 219		
	39¾	1. 000		
	36	. 914		
	29½	. 750		
	23⅝	. 600	1	2
Sweden-----	60	1. 524		
	56½	1. 434		
	42	1. 067		
	35¼	. 891		
	30	. 762	1, 375	2, 200
Switzerland-----	56½	1. 434	2, 223	3, 556
	39¾	1. 000	735	1, 176
	31½	. 800	30	48
	29½	. 750	9	14
Yugoslavia-----	56½	1. 434	5, 619	8, 990
	39¾	1. 000	104	166
	30	. 762	1, 639	2, 622
	23⅝	. 600	201	321
Asia:				
Burma-----	39¾	1. 000	1, 787	2, 859
Ceylon-----	66	1. 667	888	1, 420
	30	. 762	87	139
China-----	56½	1. 434	19, 000	30, 400
	39¾	1. 000	3, 040	4, 868
	Other	Other		
Hong Kong-----	56½	1. 434	22	35
India-----	66	1. 677	15, 696	25, 113
	39¾	1. 000	14, 969	23, 950
	30	. 762	2, 929	4, 686
	24	. 609	427	683

Table 25. Foreign Railroad Gages and Mileages—Continued

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Indochina:				
Cambodia.....	39 $\frac{3}{8}$	1. 000	240	384
North Viet-Nam.....	39 $\frac{3}{8}$	1. 000	60	96
South Viet-Nam.....	39 $\frac{3}{8}$	1. 000	780	1, 248
	31 $\frac{1}{2}$	. 800	22	35
Iran.....	56 $\frac{1}{2}$	1. 434	1, 470	2, 352
	60	1. 524	124	198
	66	1. 677	57	91
	39 $\frac{3}{8}$	1. 000	5. 6	9
	30	. 762	35. 8	57
Iraq.....	39 $\frac{3}{8}$	1. 000	722	1, 155
	56 $\frac{1}{2}$	1. 434	328	524
Israel.....	56 $\frac{1}{2}$	1. 434	162. 8	260
	41 $\frac{3}{16}$	1. 050	12. 4	19
	Dual	Dual	54	86
Japan.....	42	1. 067	15, 295	24, 614
	30	. 762		
	54	1. 372	1, 005	1, 617
	56 $\frac{1}{2}$	1. 434		
Jordan.....	41 $\frac{3}{8}$	1. 050	225	360
Korea:				
North.....	56 $\frac{1}{2}$	1. 434	1, 629	2, 716
	30	. 762	608	1, 014
South.....	56 $\frac{1}{2}$	1. 434	1, 750	2, 800
	30	. 762	150	240
			(about)	
Lebanon.....	56 $\frac{1}{2}$	1. 434	203	324
	41 $\frac{3}{8}$	1. 050	51	81
Malaya.....	39 $\frac{3}{8}$	1. 000	984	1, 574
Mongolia.....	60	1. 524	355	568
	39 $\frac{3}{8}$	1. 000	331	529
		. 700	24	38
Nepal.....	30	. 762	64	102
Pakistan:				
West.....	66	1. 677	4, 546	7, 273
	39 $\frac{3}{8}$	1. 000	319	510
	30	. 762	458	732
East.....	66	1. 677	542	867
	39 $\frac{3}{8}$	1. 000	1. 118	1, 788
	30	. 762	20	32
Saudi Arabia.....	56 $\frac{1}{2}$	1. 434	351	561
Syria.....	56 $\frac{1}{2}$	1. 434	349	558
	41 $\frac{3}{8}$	1. 050	189	302
Thailand (Siam).....	39 $\frac{3}{8}$	1. 000	2, 045	3, 272
Turkey.....	56 $\frac{1}{2}$	1. 435	4, 583	7, 332
	29 $\frac{1}{2}$	. 750	76	121
	60	1. 524	76	121

Table 25. Foreign Railroad Gages and Mileages—Continued

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Union of Soviet Socialist Republics (statistics are estimates)-----	60	1. 524	74, 500	119, 200
Africa:				
Algeria-----	56½	1. 434	1, 409	2, 254
	41⅞	1. 050	795	1, 272
	39¾	1. 000	421	673
	23⅝	. 600	90	144
Angola-----	42	1. 067	992	1, 587
	39¾	1. 000	403	644
	42	1. 067	77	123
Bechuanaland (included in figures for Rhodesia).				
Belgian Congo-----	42	1. 067	1, 767	2, 827
	39¾	1. 000	522	835
	24	. 609	87	139
	23⅝	. 600	528	844
British Somaliland (no railroads).				
Egypt-----	56½	1. 434	2, 900	4, 640
	39¾	1. 000	168	268
	30	. 762	870	1, 392
Eritrea-----	37¾	. 950	190	304
Ethiopia and French Somaliland-----	39¾	1. 000	490	784
French Cameroons-----	39¾	1. 000	313	500
French Equatorial Africa-----	42	1. 067	327	523
French Somaliland (included with Ethiopia).				
French West Africa-----	39¾	1. 000	2, 343	3, 748
Gambia (no railroads).				
Ghana (Gold Coast)-----	42	1. 067	535	856
Italian Somaliland (no railroads).				
Kenya (East African railways and harbors), includes Uganda, Kenya, and Tanganyika-----	39¾	1. 000	3, 245	5, 192
Liberia-----	42	1. 067	42	67
Libya-----	37⅞	. 950	102	163
Madagascar-----	39¾	1. 000	530	848
Mauritius-----	56½	1. 434	100	160
Morocco-----	56½	1. 434	1, 064	1, 702
Mozambique-----	42	1. 067	2, 183	3, 492
	29½	. 750	141	225

See footnotes at end of table.

Table 25. Foreign Railroad Gages and Mileages—Continued

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Nigeria-----	42	1. 067	1, 904	3, 046
	30	. 762	133	212
Nyasaland-----	42	1. 067	316	505
Portuguese Guinea (no railroads).				
Reunion-----	39½	1. 000	78	124
Rhodesia (North and South) (includes Bechuanaland).	42	1. 067	2, 436	3, 897
Sierra Leone-----	42	. 762	311	497
Sudan-----	42	1. 067	2, 011	3, 217
	24	. 609	19	30
Tanganyika-----	39½	1. 000	1, 581	2, 529
Togo-----	39½	1. 000	278	444
Tunisia-----	56½	1. 434	300	480
	39½	1. 000	1, 005	1, 608
Uganda (details included in figures for Kenya) (East African railways and harbors).*				
Union of South Africa-----	42	1. 067	12, 578	20, 124
	24	. 609	793	1, 268
North America:				
Alaska-----	56½	1. 434	536	857
	36	. 914	110	176
Canada-----	56½	1. 434	44, 741	71, 585
	42	1. 067	705	1, 128
Mexico-----	56½	1. 434	11, 154	17, 846
	36	. 914	1, 329	2, 126
United States-----	56½	1. 434	236, 415	378, 264
	36	. 914	584	934
South America:				
Argentina-----	66	1. 677	15, 192	24, 307
	56½	1. 434	2, 131	3, 409
	39½	1. 000	9, 280	14, 848
	29½	. 750	635	1, 016
Bolivia-----	39½	1. 000	1, 866	2, 985
	30	. 762	20	32
Brazil-----	63	1. 600	1, 556	2, 489
	39½	1. 000	18, 338	29, 340
	29½	. 760	452	723
	24	. 609	29	46
	23½	. 600	117	187
British Guiana-----	56½	1. 434	60	96
	42	1. 067	18	28

See footnotes at end of table.

Table 25. Foreign Railroad Gages and Mileages—Continued

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Chile-----	66	1. 677	1, 808	2, 886
	56½	1. 434	504	806
	42	1. 067	440	704
	39¾	1. 000	2, 429	3, 886
	30	. 762	181	289
	23¾	. 600	193	308
Colombia-----	39¾	1. 000	904	1, 446
	36	. 914	487	779
Ecuador-----	56½	1. 434	94	150
	42	1. 067	500	800
	29½	. 750	112	179
	(3)	(3)	122	195
French Guiana (no railroads).				
Paraguay-----	56½	1. 434	312	499
	39¾	1. 000	59	94
	31¾	. 800	57	91
	30	. 762	144	230
	29½	. 750	67	107
	24	. 609	11	17
Peru-----	56½	1. 434	1, 148	1, 836
	42	1. 067	58	92
	36	. 914	734	1, 174
	30	. 762	42	67
	29½	. 750	27	43
	23¾	. 600	151	241
Surinam (Dutch Guiana)-----	39¾	1. 000	107	171
Uruguay-----	56½	1. 434	1, 876	3, 001
	35½	. 895	3	5
	29½	. 750	9	14
Venezuela-----	42	1. 067	290	464
	39¾	1. 000	85	136
	36	. 914	108	172
	24	. 609	220	352
Central America:				
British Honduras (no railroads).				
Costa Rica-----	42	1. 067	411	657
El Salvador-----	36	. 914	385	616
Guatemala-----	36	. 914	725	1, 160
Honduras-----	42	1. 067	489	782
	36	. 914	286	457
Nicaragua-----	42	1. 067	235	376
Panama-----	60	1. 524	150	240
	36	. 914	105	168

See footnotes at end of table.

Table 25. Foreign Railroad Gages and Mileages—Continued

Country	Track gage		Total length of railroads	
	Inches	Meters	Miles	Kilometers
Caribbean:				
Cuba-----	56½	1. 434	2, 666	4, 265
	36	. 914	57	91
	30	. 762	68	108
Dominican Republic-----	42	1. 067	86	137
	30	. 762	62	99
Haiti-----	42	1. 067	112	179
	30	. 762	75	120
Jamaica-----	56½	1. 434	208	332
Puerto Rico-----	39¾	1. 000	271	433
Trinidad-----	56½	1. 434	105	168
Australasia:				
Australia-----	63	1. 600	6, 102	9, 763
	56½	1. 434	7, 294	11, 830
	42	1. 067	12, 835	20, 536
	30	. 762	114	182
	24	. 609	30	48
New Zealand-----	42	1. 067	3, 530	5, 648
Tasmania-----	42	1. 067	723	1, 156
Pacific Islands:				
Formosa-----	42	1. 067	493	788
	30	. 762	109	174
Hawaii-----	36	. 914	20	32
Hainan-----	42	1. 067	167	267
Indonesia:				
Borneo-----	39¾	1. 000	116	185
Java-----	46	1. 168	25	40
	42	1. 067	2, 665	4, 364
	23½	. 600	50	80
Madura-----	42	1. 067	140	224
Sumatra-----	42	1. 067	846	1, 353
	30	. 762	305	488
Philippines-----	42	1. 067	655	1, 048
Approximate grand totals----	-----	-----	803, 056	1, 283, 157

¹ Being converted from 23½ inch

² Kenya and Uganda.

³ Not available

⁴ Plus 28 miles of dual gage.

Section VI. SPECIAL DATA

29. Logistics of Prefabricated Buildings

Logistics of prefabricated buildings are given in table 26.

Table 26. Prefabricated Buildings

Type of building	Size (feet)	Shipping data	
		Number of packages	Measurement tons
Quonset building (Great Lakes Steel) ..	40 by 100	20	9.6
Metal, arch rib (Steelcraft)	40 by 100	20	9.7
Metal, rigid frame (Butler)	40 by 100	22	12.2
Advance base hut, steel, northern type (Steelcraft).	20 by 48	11	6.1
Steel, vertical wall:			
(1) Steelcraft	20 by 48	14	8.3
(2) Great Lakes Steel	20 by 48	11	7.1
Arctic, wood panel, frameless	20 by 48	6	26.0
Barracks, wood frame and plywood	20 by 48	-----	40.3
Nissen hut, British	16 by 36	-----	14.0
Do	24 by 36	-----	21.0

30. Shipping Characteristics of Weapons

The shipping characteristics of certain weapons issued to engineer units are shown in table 27.

31. Gases and Gas Cylinders

a. Characteristics. The characteristics of certain gases which are used in industry and in the Army, and which are stored and shipped in a compressed state, are shown in table 28.

b. U.S. and Foreign Cylinders.

- (1) In the United States, cylinders for compressed gases are manufactured under various ICC specifications. For details see AR 700-8120-1.
- (2) Figure 7 shows the locations of identifying colors on bottle-type cylinders as specified in Mil-Std-101-A. Table 29(1) shows the color code which is used under U.S. military standards to identify the contents of cylinders. Table 29(2) shows the color codes for certain gases in use in four foreign countries. Table 30 shows the characteristics of the cylinders used for certain of the more common gases.

Table 27. Shipping Characteristics of Weapons

Nomenclature	Item weight (pounds)	Type container	Items per container	Dimensions of container				Shipping weight (pounds) per container	Measurement tons per container	Container per vehicle	
				Length (feet)	Width (feet)	Height (feet)	Cubic feet			2½-ton truck	40-foot, 40-ton R.R. (box) car (70 percent cubage capacity load)
Carbine, cal. .30, M1-----	5.5	Wood box----	10	3.48	1.42	0.98	4.82	112.0	.12	58	450
Gun, automatic, 20 mm., M24A1.	100.0	Wood box----	1	7.1	9.58	.792	5.39	170.0	.135	47	400
Gun, machine, cal. .30, Browning M1919A4, w/eqp	37.0	Wood box----	1	3.8	.58	.75	1.65	55.0	.04	172	1,315
Gun, machine, cal. .50, Browning, M3, aircraft.	64.5	Wood box----	1	5.1	.687	.843	2.96	97.0	.074	77	718
Gun, machine, 7.62 mm., M60.	45.0	Wood box----	2	3.1	1.7	1.1	6	123.5	.15	65	270
Gun, submachine, cal. .45, M3 and M3A1.	8.0	Wood box----	10	1.65	1.26	1.42	2.96	128.0	.074	63	630
Gun, machine, cal. .30, Browning 1919A6 w/eqp.	39.0	Wood box----	1	3.8	.56	.75	1.6	58.5	.4	178	1,355
Mortar, 60 mm., M5 Mount--	45.5	Wood box----	1	2.34	1.16	11.2	3.04	75.0	.076	95	715
Mortar, 81 mm., M4 Mount--	136.5	Wood box----	1	4.68	1.5	1.25	8.59	210.0	.214	33	252
Mount, machine gun, M91---	10.0	Wood box----	3	2.8	2	1.08	6	120.0	.15	47	362
Pistol, auto. cal. 145 M-1911A1 w/50 extra mags.	2.5	Wood box----	25	2.82	.98	.868	2.38	105.0	.059	76	760
Rifle, recoilless, 57 mm., M18A.	44.5	Wood box----	1	5.55	1.39	1.33	10.329	115.0	.258	28	212
Rifle, recoilless, 75 mm., M20-	114.5	Wood box----	1	7.12	1.47	1.14	11.93	240.0	.298	24	182
Rifle, recoilless, 106 mm., M40A1, w/eqp.	840.0	Wood box----	1	7.3	3.2	3.8	77.5	1,110.0	1.94	4	28

Rifle, U.S., cal. 130, M1-----	9. 50	Wood box----	10	4. 08	1. 54	1. 08	6. 82	164. 0	. 17	42	319
Rifle, 7.62 mm., M14-----	8. 7	Wood box----	10	4. 23	1. 8	1. 1	8	200. 0	. 2	35	271
Rocket launcher, 3.5-in., M20.	17. 0	VCI package--	4	3. 01	2. 79	1. 33	11. 23	135. 0	. 28	25	194
Sniperscope-----	136. 0	Wood box----	1	3. 4	1. 5	1. 5	7. 4	188. 0	. 185	39	294

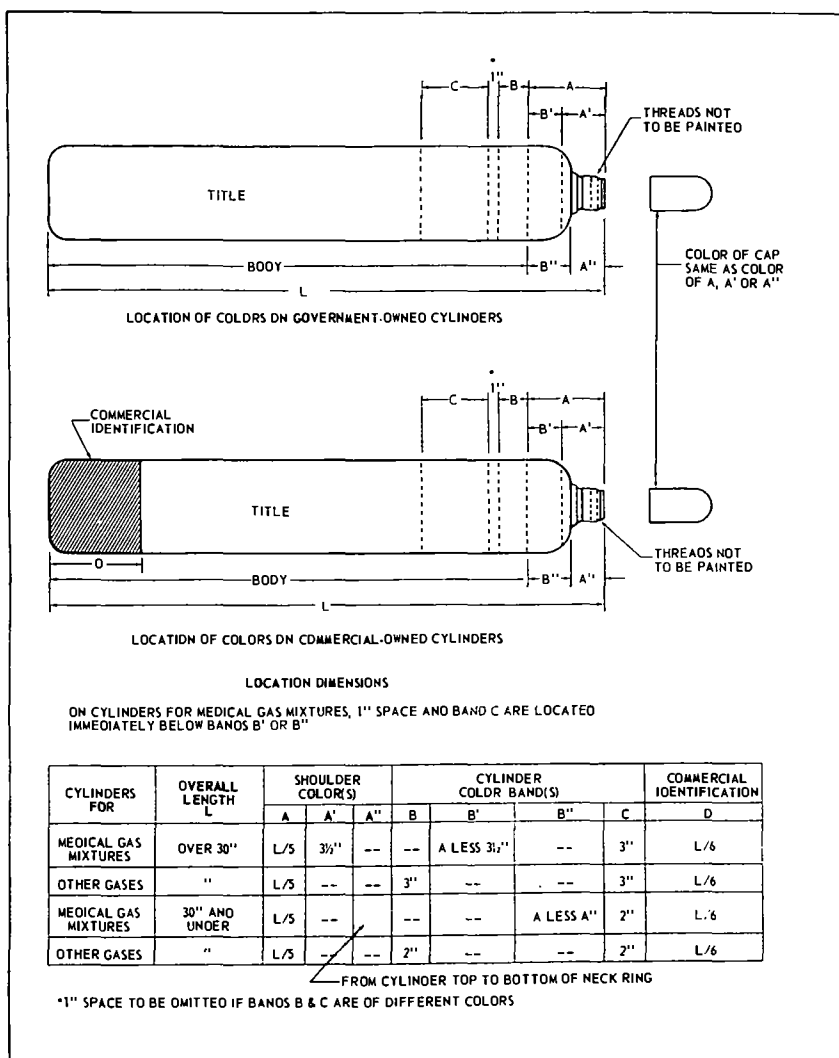


Figure 7. Location of colors in bottle-type cylinders.

Table 28. Characteristics of Gases

Gas	Color	Odor	Weight when compared to air	Physical state as shipped	Physical effect
Acetylene.....	None.....	Garliclike.....	Lighter.....	Dissolved.....	Anesthetic.
Ammonia.....	None.....	Pungent.....	Lighter.....	Liquid.....	Irritant.
Argon.....	None.....	None.....	Slightly heavier.....	Liquid.....	None. ¹
Carbon dioxide.....	None.....	Faint.....	Much heavier.....	Liquid.....	None. ¹
Chlorine.....	Greenish yellow.....	Disagreeable.....	Much heavier.....	Liquid.....	Irritant.
Ethylene oxide.....	None.....	Pungent.....	Lighter.....	Liquid.....	Irritant.
Helium.....	None.....	None.....	Much lighter.....	Gas.....	None. ¹
Hydrogen.....	None.....	None.....	Much lighter.....	Gas.....	None. ¹
Hydrogen cyanide.....	None.....	Peach blossom.....	Lighter.....	Liquid.....	Toxic.
Methyl chloride.....	None.....	Etherlike.....	Heavier.....	Liquid.....	Anesthetic.
Nitrogen.....	None.....	None.....	Slightly lighter.....	Gas.....	None. ¹
Oxygen.....	None.....	None.....	Slightly heavier.....	Gas.....	None.
Petroleum gas—Butane propane.	None.....	Sewer gas.....	Heavier.....	Liquid.....	Anesthetic.
Refrigerant.....	None.....	None.....	Heavier.....	Liquid.....	None. ¹
Sulphur dioxide.....	None.....	Rotten eggs.....	Much heavier.....	Liquid.....	Irritant.

¹ Excessive amounts cause suffocation.

Table 29(1). Military Standard 101A—Color Code for Compressed Gas Cylinders and Pipelines

Title	Top A	Band B	Band C	Body
Acetylene.....	Yellow.....	Yellow.....	Yellow.....	Yellow.
Acrolein.....	Yellow.....	Brown.....	Black.....	Brown.
Aerosol insecticide.....	Buff.....	Buff.....	Buff.....	Buff.
Air, oil pumped.....	Black.....	Green.....	Green.....	Black.
Air, water pumped.....	Black.....	Green.....	Black.....	Black.
Ammonia.....	Brown.....	Yellow.....	Orange.....	Orange.
Argon, oil pumped.....	Gray.....	White.....	White.....	Gray.
Argon, water pumped.....	Gray.....	White.....	Gray.....	Gray.
Boron trichloride.....	Gray.....	Brown.....	Gray.....	Brown.
Boron trifluoride.....	Gray.....	Brown.....	Brown.....	Brown.
Bromoacetone.....	Brown.....	Black.....	Black.....	Brown.
Bromochloromethane.....	Buff.....	Gray.....	Buff.....	Buff.
Bromochloromethane (fire only).....	Red.....	Gray.....	Red.....	Red.
Bromofluoromethane.....	Orange.....	White.....	Gray.....	Orange.
Bromofluoromethane (fire only).....	Red.....	White.....	Gray.....	Red.
Butadiene.....	Yellow.....	White.....	Buff.....	Buff.
Carbon dioxide.....	Gray.....	Gray.....	Gray.....	Gray.
Carbon dioxide (fire only).....	Red.....	Red.....	Red.....	Red.
Carbon monoxide.....	Yellow.....	Brown.....	Brown.....	Brown.
Chloroacetone.....	Black.....	Brown.....	Black.....	Brown.
Chlorine.....	Brown.....	Brown.....	Brown.....	Brown.
Chlorine trifluoride.....	Brown.....	Green.....	Brown.....	Brown.
Chloropicrin.....	Brown.....	Orange.....	Orange.....	Brown.
Cyanogen.....	Yellow.....	Brown.....	Yellow.....	Brown.
Cyclopropane, medical.....	Orange.....	Yellow.....	Blue.....	Blue.
Cyclopropane, medical.....	Orange.....	Chromium plated.....	Chromium plated.....	Chromium plated.
Dibromodifluoromethane.....	Buff.....	White.....	Buff.....	Buff.

Dibromodifluoromethane (fire only).....	Red.....	White.....	Red.....	Red.....
Difluorochloroethane.....	Gray.....	Yellow.....	Yellow.....	Orange.....
Difluoroethane.....	Gray.....	Yellow.....	Orange.....	Orange.....
Dimethylamine, anhydrous.....	Yellow.....	Blue.....	White.....	Buff.....
Dimethylether.....	Yellow.....	Brown.....	Buff.....	Buff.....
Dispersant, Dichlorodifluoromethane-Difluoroethane Mix.....	Buff.....	Gray.....	Gray.....	Buff.....
Ethane.....	Yellow.....	Blue.....	Yellow.....	Yellow.....
Ethyl chloride.....	Buff.....	Blue.....	Yellow.....	Buff.....
Ethyl nitrite.....	Yellow.....	Buff.....	Buff.....	Buff.....
Ethylamine, anhydrous.....	Yellow.....	Blue.....	Blue.....	Buff.....
Ethylene, industrial.....	Blue.....	Yellow.....	Buff.....	Buff.....
Ethylene, medical.....	Yellow.....	Blue.....	Blue.....	Blue.....
Ethylene oxide.....	Yellow.....	Blue.....	Buff.....	Buff.....
F-11, Trichlorofluoromethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-12, Dichlorodifluoromethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-13, Chlorotrifluoromethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-21, Dichlorofluoromethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-22, Chlorodifluoromethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-113, Trichlorotrifluoroethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-114, Dichlorotetrafluoroethane.....	Orange.....	Orange.....	Orange.....	Orange.....
F-124A, Chlorotetrafluoroethane.....	Orange.....	Orange.....	Orange.....	Orange.....
Fluorine.....	Brown.....	Green.....	Green.....	Brown.....
Fumigant, Carbon dioxide-Ethylene oxide.....	Buff.....	Blue.....	Buff.....	Buff.....
Helium, oil free or medical.....	Buff.....	Gray.....	Gray.....	Gray.....
Helium, oil pumped.....	Gray.....	Orange.....	Gray.....	Gray.....
Helium-Oxygen.....	Buff ¹	White ²	Green.....	Green.....
Hydrogen.....	Yellow.....	Black.....	Yellow.....	Yellow.....
Hydrogen bromide.....	Black.....	Brown.....	Brown.....	Brown.....
Hydrogen chloride, anhydrous.....	Brown.....	White.....	Brown.....	Brown.....
Hydrogen cyanide, anhydrous.....	Yellow.....	Brown.....	White.....	Brown.....
Hydrogen fluoride, anhydrous.....	Green.....	Brown.....	Brown.....	Brown.....

See footnotes at end of table.

Table 29(1). Military Standard 101A—Color Code for Compressed Gas Cylinders and Pipelines—Continued

Title	Top A	Band B	Band C	Body
Hydrogen sulfide.....	Brown.....	Yellow.....	Brown.....	Brown.
Krypton, oil pumped.....	Gray.....	Buff.....	Buff.....	Gray.
Krypton, water pumped.....	Gray.....	Buff.....	Gray.....	Gray.
Manufactured Gas—(Specify) Coal, oil, water, producer, etc.	Brown.....	Yellow.....	Yellow.....	Yellow.
Methane.....	Yellow.....	White.....	Yellow.....	Yellow.
Methylamine.....	Yellow.....	Brown.....	Yellow.....	Buff.
Methyl bromide.....	Brown.....	Black.....	Brown.....	Brown.
Methyl bromide (fire only).....	Red.....	Brown.....	Red.....	Red.
Methyl chloride.....	Yellow.....	Brown.....	Orange.....	Orange.
Methyl mercaptan.....	Brown.....	Yellow.....	Yellow.....	Brown.
Methyl sulfide.....	Yellow.....	Brown.....	Buff.....	Brown.
Methylene chloride.....	Gray.....	Blue.....	Orange.....	Orange.
Natural gas.....	Yellow.....	Brown.....	Yellow.....	Yellow.
Neon, oil pumped.....	White.....	Buff.....	Gray.....	Gray.
Neon, water pumped.....	White.....	Buff.....	Buff.....	Gray.
Nickel carbonyl.....	Yellow.....	White.....	Yellow.....	Brown.
Nitric oxide.....	Brown.....	Buff.....	Brown.....	Brown.
Nitrogen dioxide.....	Brown.....	Buff.....	Buff.....	Brown.
Nitrogen, oil pumped.....	Gray.....	Black.....	Gray.....	Gray.
Nitrogen, water pumped.....	Gray.....	Black.....	Black.....	Gray.
Nitrosyl chloride.....	Brown.....	White.....	White.....	Brown.
Nitrous oxide.....	Blue.....	Blue.....	Blue.....	Blue.
Oxygen, medical.....	White.....	Green.....	Green.....	Green.
Oxygen, aviator's.....	Green.....	White.....	Green.....	Green.
Oxygen.....	Green.....	Green.....	Green.....	Green.
Oxygen-Carbon dioxide.....	Gray ¹	White ²	Green.....	Green.

Petroleum Gas—(Specify) Acetogen, Butane, Butane-Propane, Butene-1, Cyclopropane, Isobutane, Isobutylene, Neopentane, Propane, etc.	Yellow	Orange	Yellow	Yellow.
Phenylcarbylamine chloride	Brown	Gray	Gray	Brown.
Phosgene	Brown	Orange	Brown	Brown.
Propylene	Yellow	Gray	Buff	Buff.
Sulfur dioxide	Brown	Gray	Brown	Brown.
Sulfur hexafluoride	Gray	White	Black	Gray.
Tetrafluoroethylene, inhibited	Buff	White	White	Buff.
Trimethylamine, anhydrous	Yellow	Blue	Orange	Buff.
Vinyl bromide	Buff	Blue	Blue	Buff.
Vinyl chloride	Yellow	Orange	Buff	Buff.
Vinyl methyl ether, inhibited	Yellow	Black	Buff	Buff.
Xenon, oil pumped	White	Black	Black	Gray.
Xenon, water pumped	White	Black	Gray	Gray.

¹ A' or A'' for medical gas mixtures.

² B' or B'' for medical gas mixtures.

Table 29(2). Foreign Cylinder Colors

Gas	England	Australia	Japan	Italy	Germany
Acetylene	Purple	Maroon	Brown	Orange	Yellow.
Carbon dioxide	Black	Brown		Yellow	
Freon 12		Light green			
Helium	Brown	Gray			Red.
Hydrogen	Red	Signal red	Red	Red	
Methyl chloride		Light green			
Nitrogen	Gray	Dark gray	Purple	Green	Green.
Oxygen	Black	Black	Black	White	Blue.

Table 30. Characteristics of Cylinders Used for Certain Gases

Gas	Standard cylinder characteristics								
	ICC spec. number stamped on shoulder	Capacity cu. ft. of gas at atmospheric pressure	Capacity (lb. liquid)	Outside diameter (inches)	Length (inches)	Max pressure (p.s.i. at 70° F.)	Weight empty (lb.)	Weight full (lb.)	Outlet valve threads ¹
Acetylene.....	8	10	-----	4 $\frac{7}{16}$	13 $\frac{1}{8}$	250	92	100	Internal-left.
		40	-----	7 $\frac{1}{8}$	26	-----	100	196	
		100-110	-----	8 $\frac{1}{2}$	30	-----	-----	-----	
		225	-----	12 $\frac{1}{2}$	36	-----	-----	-----	
		300	-----	12 $\frac{1}{4}$	39	-----	-----	-----	
Ammonia.....	4A	-----	100	12 $\frac{1}{2}$	52 $\frac{3}{4}$	480	-----	-----	Internal-right.
		-----	150	15	53	-----	-----	-----	
Carbon dioxide.....	3A	-----	20	7 $\frac{1}{8}$	29 $\frac{1}{2}$	2, 015	68	88	External-right.
Chlorine.....	3A	-----	50	8 $\frac{1}{2}$	51	-----	108	158	External-right.
		-----	10	4 $\frac{1}{2}$	21	480	-----	-----	
		-----	16	6 $\frac{1}{2}$	13 $\frac{3}{4}$	-----	-----	-----	
		-----	150	10 $\frac{1}{2}$	48 $\frac{5}{8}$	-----	-----	-----	
Helium.....	3A	220	-----	9	51	2, 015	120	122	(2) External-left.
Hydrogen.....	3A	115	-----	7 $\frac{1}{8}$	43	2, 015	120	121	
Methyl chloride.....	4B	220-240	-----	9	51	2, 015	120	121	External-right.
		-----	15	7	21 $\frac{1}{2}$	300	-----	-----	
		-----	30	8 $\frac{1}{2}$	27	-----	-----	-----	
		-----	93	10 $\frac{1}{2}$	49 $\frac{1}{2}$	-----	-----	-----	
		-----	100	10 $\frac{1}{2}$	49 $\frac{1}{2}$	-----	-----	-----	

Nitrogen (water-pumped)-(oil-pumped).	3A	220	-----	9	51	2, 015	120	137	Internal-right.
		220	-----	9	51	-----	120	137	Internal-left.
Oxygen-----	3A	12	-----	$4\frac{7}{16}$	$16\frac{1}{4}$	2, 015	79	88	External-right.
		110	-----	$7\frac{7}{8}$	43	-----	120	137	
		220-240	-----			-----			
Sulfur dioxide-----	3B	-----	150	$10\frac{1}{2}$	$49\frac{1}{2}$	300	-----	-----	External-right.

¹ From U.S. Dept. of Commerce, National Bureau of Standards, Supplement to Screw-Thread Standards for Federal Services, 1944 (Issued 15 June 1949), Supplement to Handbook H28 (1944).

² Water-pumped: Internal-right. Oil-pumped: Internal-left.

32. Processing and Packing

a. General. Processing and packing supplies is a highly important step connected with the shipment or storage of items so that when required they will be in usable condition. Steps in the above include proper cleaning, application of preservatives, packaging, and crating. Processing materials and their sources are dealt with in SB 38-100.

b. Cleaning. The first step in the procedure is the proper cleaning of the item. No preservative method will protect a part from corrosion if contaminating residues (deposits foreign to the composition of the part) are present on the surface.

(1) Some causes of corrosion are:

- (a) Moisture.
- (b) Perspiration from handling.
- (c) Residual soldering, welding, or brazing fluxes.
- (d) Cutting, cooling, buffing, or grinding compounds.
- (e) Dust and chemical deposits.

(2) There can be no standard choice or method of cleaning, since the cleaner selected and the method used are dependent upon the composition, nature, and construction of the part; the nature of contaminants to be removed; the degree of cleanliness required; and the availability of cleaning materials.

(a) The extent of cleaning is determined by the surface to be cleaned, varying from a highly finished part to a rough casting. Naturally, the utmost care must be taken to remove even fingerprints from highly finished surfaces.

(b) There are four approved types of cleaning materials, plus fingerprint remover or neutralizer. These are:

1. Petroleum solvent (Stoddard).
2. Alkaline cleaners.
3. Emulsifiable solvents.
4. Vapor degreasers (trichlorethylene and perchlorethylene).
5. Methanol (fingerprinting neutralizer).

(c) The parts must be dried after cleaning and before applying the preservative. Preferably, drying is done with compressed air or by oven-drying. Drying with a cloth is not recommended and should be used only when compressed air or oven-drying is impracticable.

c. Preservatives. The types of preservatives recommended are given in table 31. Further information may be obtained by reference to TM 38-230. The application of preservatives may be done by dipping, spraying, brushing, flow-coating, or slushing. Dipping is the preferred method.

d. Methods of Preservation. There are six basic methods of preservation, and a number of submethods, which are used in the processing

Table 31. Preservative Compound Chart¹

Type	Preservative	Military	Aeronautical	Army	Navy	Application ² method and temp.	Description ³	Use ⁴
P-1	Thin film preservative (hard-drying, cold application).	MIL-C-16173, grade 1.				Brush, dip, or spray. 40° F.-95° F.	Dries to a hard film. Thickness 0.004 in. (max.). Solvent entback. Flash point 100° F.	On metals under outdoor conditions. Primarily for parts not having highly finished surfaces. Not satisfactory for parts or equipment damaged by solvent removal. NOT FOR INTRICATE ASSEMBLIES. Can frequently be used without overwrap.
P-2	Thin film preservative (soft film, cold application).	MIL-C-16173, grade 2				Brush, dip, or spray. 40° F.-95° F.	Non-hard-drying film. Thickness 0.002 in. (max.). Solvent entback. Flash point 100° F.	On metals indoors where easy removability is desired. Usually requires overwrap.
P-3	Thin film preservative (soft, cold application, water displacing).	MIL-C-16173, grade 3.				Brush, dip, or spray 40° F.-95° F.	Non-hard-drying film. Thickness 0.001 in. (max.). Solvent entback. Flash point 100° F. Also removable in hot water.	To displace water from previously wet surface. Usable for temporary protection.
P-4	Heavy preservative (hot application, hard film).	MIL-C-11796, class 1.				Brush or dip. Maximum temperature of application 200° F.	Thick, hard drying, greasy film.	Protection of highly finished parts of simple design for prolonged periods.
P-5	Medium preservative (hot application, soft film).	MIL-C-11796, class 2.			MIL-C-18487.	Brush, dip, or spray. Maximum temperature of application 190° F.	Thick, medium firm, greasy film.	Protection of highly finished parts of relatively simple design for prolonged periods. Requires overwrap.
P-6	Light preservative (hot application, soft film).	MIL-C-11796, class 3.				Brush, dip, or spray. Maximum temperature of application 180° F.	Thin, soft, greaselike film.	Protection of highly finished parts of complex design which can be cleaned. Especially adapted to preserving antifriction bearings. Requires overwrap.
P-7	Medium preservative oil (cold application).	MIL-L-3150				Brush, dip, or spray. 60° F.-120° F.	Lube oil with added inhibitors. Similar in physical properties to SAE 30. Pour point 20° F.	Protection of oil-lubricated and similar operating parts. Should be supplemented by Method IA or II DO NOT USE FOR INTERNAL COMBUSTION ENGINES. Must be removed prior to use.

See footnotes at end of table.

Table 31. Preservative Compound Chart¹—Continued

Type	Preservative	Military	Aeronautical	Army	Navy	Application ² method and temp.	Description ³	Use ⁴
P-8	Light preservative oil (cold application).	MIL-L-3503.	-----	-----	-----	Brush, dip, or spray. 60° F.-120° F.	Lube oil with added inhibitors. Flash point 300° F. Pour point 50° F. Similar in physical properties to SAE 10.	Protection of machine guns and small arms, and operating equipment. Must be removed prior to use in Arctic or in an airplane.
P-9	Very light preservative oil (cold application).	MIL-L-644.	-----	-----	-----	Brush, dip, or spray. 60° F.-120° F.	Lube oil with added inhibitors. Flash point 275° F. Pour point 70° F.	Protection of machine guns and small arms, and operating equipment. Need not be removed from guns prior to use.
P-10	Engine preservative oil.	-----	MIL-C-6529.	MIL-L-21260, Grade 1, 2, or 3.	MIL-L-21260, Grade 1, 2, or 3.	Brush, dip, or spray. 60° F.-120° F.	Engine lubricating oil with corrosion inhibitors, including hydrobromic acid neutralizers. Pour point MIL-L-21260, grade 1, 10° F. MIL-L-21260, grade 2, 0° F. MIL-C-6529, 10° F. Flash point: MIL-L-21260, grade 1, 360° F. MIL-L-21260, grade 2, 390° F. MIL-C-6529, 350° F.	Protection of internal surface of internal combustion engines and other intricate assemblies.
P-11	Preservative grease (application as required).	-----	MIL-G-3278.	MIL-G-10924.	MIL-G-16908.	Brush. 30° F.-120° F.	Lithium soap grease-----	Protective grease for lubricated bearings. Particularly suitable for equipment which must operate at both very low and high temperatures.
P-12	Anti-friction bearing preservative (hot application).	-----	MIL-C-11796, Class 3.	-----	-----	Dip. 170° F.-180° F.	Medium dark soft petroleum base material. Flash point 350° F.	Preservative grease for lubricating bearings and other semi-complex parts from which it can be removed.
P-13	Wax emulsion-----	MIL-W-3688.	-----	-----	-----	Spray, dip, or wipe. Room temperature.	Aqueous uniform combination of emulsifying agents, waxes, and resins together with suitable rust inhibitors. Softening point 165° F.	Dry lubricant and rust inhibiting coating for general weatherproofing when applied to articles.

P-14	Corrosion preventive for food handling machinery and equipment (non-toxic).	MIL-C-10382.				Spray room temperature.	Uniform mixture of white microcrystalline wax, kerosene corrosion inhibitor, 2-Amino-2-Methyl-1-Propanol, and solvent P-S-661 produces a thin film easily removed. Flash point 100° F.	Food handling equipment and machinery.
P-15	Hydraulic system preservative oil. ¹							
P-16	Thixotropic preservative oil.	MIL-C-5545.				Brush, dip, or spray. 120° F. 180° F.	Lube oil with added thickeners and corrosion inhibitors with thixotropic behavior. Flash point 350° F.	Protection of internal and external surfaces and assemblies where runoff cannot be tolerated. Primarily for aircraft engines.
P-17	Instrument bearing preservative oil.	MIL-L-6085.				Brush, dip, or spray. Room temperature	Synthetic base lubricating oil of low volatility with additive materials to impart oxidation stability and corrosion protective properties. Pour point 70° F. Flash point 365° F.	Aircraft instruments and electronic equipment.
P-18	Volatile corrosion inhibitor.	MIL-P-3420.				Wrap of VCI treated material.	Materials coated or impregnated with a corrosion inhibitor which will volatilize and whose vapors prevent rusting of metal surfaces.	Protection of ferrous metals, improved nonferrous metals and approved nonmetallic components during shipment, handling, and storage.

¹ *Warning.*—This table is intended to correlate specification numbers with certain generally accepted types. It does not connote interchangeability, except that any compound listed under MILITARY may be used for any other with the same P number. It may, however, be used for the selection of alternative preservative compounds when the specific preservatives are not in stock or available from another source in sufficient time to accomplish the necessary preservation and when there are no specific orders to the contrary. This table is not intended to be used by contractors for the selection of alternate preservative materials unless such selection privilege is included in their contracts.

² These values are typical. Consult can label for detailed information.

³ These are typical of the most easily recognized properties.

⁴ These are the most common uses. There are many others.

⁵ Specifications for hydraulic preservative oils have not been listed because of variations in system requirements. Hydraulic preservatives used will be subject to approval by the procuring agency.

of parts and equipment. The method used depends upon the nature of the material and equipment and the degree of protection required.

- (1) *Method I. Preservative coating, with greaseproof wrap when required.* Method I is used for the protection of spare parts and other equipment for shipment and storage, when the nature and construction of the items allow ready application of a corrosive protective compound film by dipping, spraying, flushing, brushing, or fogging.
- (2) *Method IA. Water-vaporproof inclosure with preservative as required.* Method IA is intended to afford adequate protection against corrosion caused by water or water vapor, and is applied to parts and equipment where critical functioning surfaces held to close tolerances are involved. There are sixteen submethods.
- (3) *Method IB. Strippable compound coating (hot dip).* The use of Method IB is limited to parts that have no deep recesses or complexities of structure which would prevent complete removal of the plastic coating, and whose design or contour is simple. There are two submethods.
- (4) *Method IC. Waterproof barrier (with preservative as required).* Method IC is intended to afford adequate protection against deterioration caused by direct entry of water. This is effected by a sealed waterproof or water-resistant barrier permitting only water-vapor penetration to the preserved part. There are six submethods.
- (5) *Method II. Water-vaporproof barrier with desiccant and with preservative when required.* Method II is used for items of a highly critical nature requiring the highest degree of protection from damage by the effects of water vapor. It is applicable to mechanical or electrical items including assemblies with functional components which, by their nature, cannot be treated with a preservative. It involves inclosing the item(s) or assembly with the required amount of activated desiccant within a water-vaporproof barrier. There are six submethods.
- (6) *Method III. Packaging for mechanical and physical protection only.* Items packaged by Method III should be tied together or inclosed with wrappings, bags, cartons, boxes, or other containers as applicable, to the extent necessary to provide protection from hazards of contamination and physical damage encountered in general handling, storage, and issue.

e. *Packaging and Crating.*

- (1) *General.* In selecting a container for shipping, the following factors should be considered:
 - (a) Suitability of articles to be packed.

- (b) Processing used for protection against corrosion.
 - (c) Availability.
 - (d) Cubic displacement.
 - (e) Ease in handling and storing.
 - (f) Type of load.
- (2) *Cushioning material.* Soft material should be used as cushioning for delicate or fragile items; highly finished surfaces; small projections; protection of moisture-vaporproof and waterproof barriers, etc. However, cushioning material is not used in place of blocking material except in unavoidable cases.
- (3) *Lumber.* The type and thickness of lumber to be used depends on the weight of the articles to be packed. Knots, cross-grain, bark, and other defects sharply reduce the strength of a board. In cutting out lumber, defects over one-third the board width are eliminated.
- (4) *Nails.*
- (a) When nailing lumber together flatwise, nails are driven through and clinched about $\frac{1}{4}$ inch if the combined thickness of lumber is 3 inches or less.
 - (b) For thickness over 3 inches, or for nailing a flat to an edge, unclined nails are used in lengths as long as practicable without splitting the lumber. The minimum nail length to be embedded in the piece holding the point of the nail is two-thirds the nail length for 10d and smaller nails; $1\frac{1}{2}$ inches for 12d and larger nails (Spec. MIL-C-104).
- (5) *Gross weights.* Maximum gross weights for various styles of boxes and crates are given in Table 32.

Table 32. *Maximum Gross Weights for Boxes and Crates*

Specification	Type of container	Maximum gross weight, pounds
MIL-C-104.....	Crate, sheated, wood, nailed.....	30, 000
MIL-C-132.....	Crate, unsheated, wood, nailed:	
	Style A.....	1, 000
	Style A-1.....	250
	Style B.....	2, 500
	Style C.....	500
PPP-B-621.....	Box, wood, nailed:	
	Style 1.....	1 50
	Styles 2, 2½, 3.....	1, 000
	Styles 4, 5.....	400
	Style 6.....	50
PPP-B-601.....	Box, wood, cleated, plywood.....	1, 000
MIL-B-107.....	Box, wood, wirebound.....	300
PPP-B-591.....	Box, wood, cleated, fiberwood.....	200

¹ Under certain conditions, 100 lb. See Spec. PPP-B-621.

(6) *Design.* Figure 6 shows box styles. Table 33(1) shows minimum thicknesses of box parts for various styles of box and weights of contents, for domestic shipment and easy or average loads. Table 33(2) gives similar data for overseas shipments. For the case of difficult loads, and for other details, see Spec. PPP-B-621. The four groups of woods, as the term is used here, are as follows:

Group I

Alder, red	Chestnut	Pine (except southern
Aspen (Popple)	Cucumbertree	yellow)
Basswood	Cottonwood	Poplar, yellow
Buckeye	Cypress	Redwood
Butternut	Fir (true firs)	Spruce
Cedar	Magnolia	Willow

Group II

Douglas-fir	Larch, western	Tamarack
Hemlock	Pine (southern yellow)	

Group III

Ash (except white ash)	Maple, soft	Sycamore
Cherry	Sweetgum	Tupelo
Elm, soft		

Group IV

Ash, white	Hackberry	Locust
Beech	Hickory	Maple, hard
Birch	Pecan	Oak
Elm, rock		

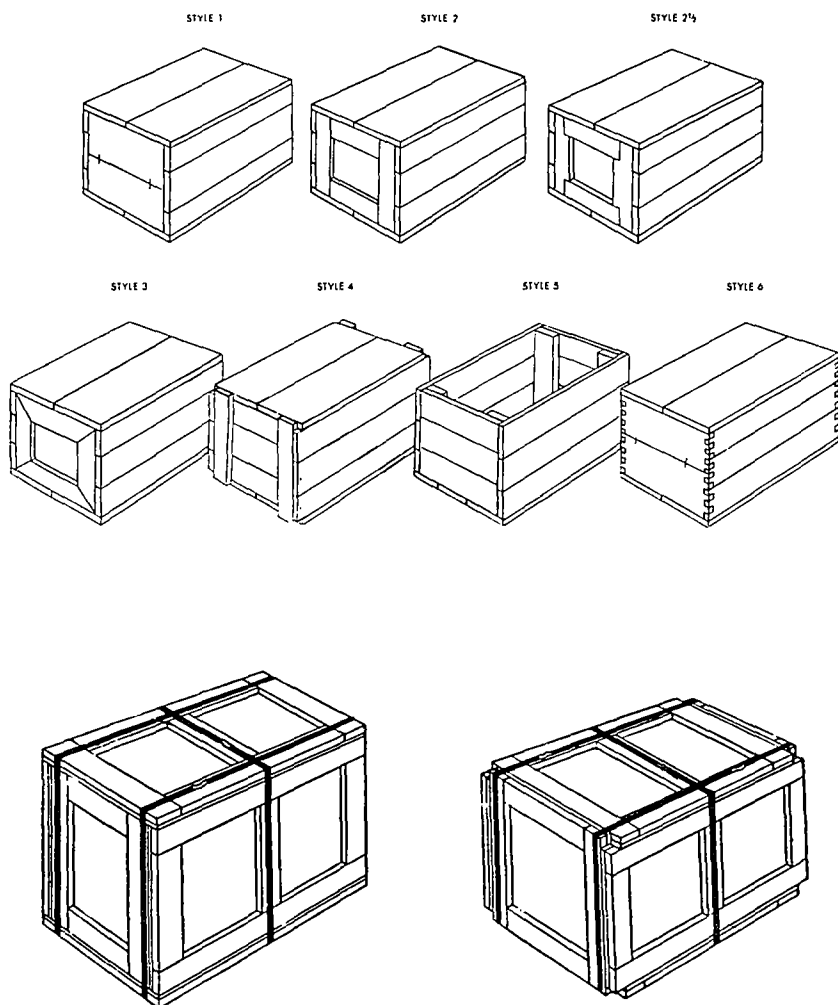


Figure 8. Box styles.

Table 33(1)

Boxes for domestic shipment, type 1 (easy) and type 2 (average) loads; minimum thickness of sides, tops, bottoms, and ends, and minimum thickness and width of cleats.

Weight of contents		Style of box	Groups I and II woods			Groups III and IV woods		
Exceeding—	Not exceeding—		Minimum thickness of sides, tops, and bottoms ¹	Minimum thickness of ends ¹	Minimum thickness and width of cleats	Minimum thickness of sides, tops, and bottoms ¹	Minimum thickness of ends	Minimum thickness and width of cleats
<i>Pounds</i>	<i>Pounds</i>		<i>Inch</i>	<i>Inch</i>	<i>Inches</i>	<i>Inch</i>	<i>Inch</i>	<i>Inches</i>
	50	1.....	$\frac{5}{16}$	$\frac{1}{2}$	-----	$\frac{1}{4}$	$\frac{1}{2}$	-----
	50	4, 4½, 5.....	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{1}{2}$ by 1¾.....	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$ by 1¾.
	50	2.....	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$ by 1½.....	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$ by 1½.
	50	6.....	$\frac{1}{4}$	$\frac{1}{2}$	-----	$\frac{3}{16}$	$\frac{3}{8}$	-----
50	100	1 ²	$\frac{3}{8}$	$\frac{3}{4}$	-----	$\frac{5}{16}$	$\frac{5}{8}$	-----
50	100	4, 4½, 5.....	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{8}$ by 2¼.....	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$ by 1¾.
50	100	2.....	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$ by 1¾.....	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{1}{2}$ by 1¾.
50	100	26.....	$\frac{3}{8}$	$\frac{3}{4}$	-----	$\frac{5}{16}$	$\frac{5}{8}$	-----
100	250	4, 4½, 5.....	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$ by 2¼.....	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8}$ by 2¼.
100	250	2, 2½, 3.....	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$ by 1¾.....	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{5}{16}$ by 1¾.
250	³ 400	2, 2½.....	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$ by 2½.....	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$ by 2¼.

¹ Thicknesses are minimum as stated; however, if parts are surfaced on both sides, thickness may be ½2-inch less than given in the table

² Style 1 and style 6 boxes may be used to carry a net weight exceeding 50 pounds

but not exceeding 100 pounds, if the boxes have one-piece sides of sawed lumber and when the contents are packed in interior containers.

³ Weights of contents exceeding 400 pounds shall be considered type 3 load.

Table 33(2)

Boxes for overseas shipment, type 1 (easy) and type 2 (average) load—determination of minimum thickness of sides, tops, bottoms, and ends, and minimum thickness and width of cleats for styles 2, 2½, 3, 4, and 5 nailed wood boxes.

Weight of contents		Style of box	Groups I and II woods			Groups III and IV woods		
Exceed- ing—	Not ex- ceeding—		Minimum thickness of sides, tops, and bottoms ²	Minimum thickness of ends ²	Minimum thickness and width of cleats ¹	Minimum thickness of sides, tops, and bottoms ²	Minimum thickness of ends ²	Minimum thickness and width of cleats ¹
<i>Pounds</i>	<i>Pounds</i>		<i>Inch</i>	<i>Inch</i>	<i>Inches</i>	<i>Inch</i>	<i>Inch</i>	<i>Inches</i>
	50	4, 4½, 5-----	⅜	⅝	⅝ by 1¾-----	⅝ ₁₆	⅝	⅝ by 1¾.
50	100	4, 4½, 5-----	⅜ ₁₆	¾	¾ by 2¼-----	¾	⅝	⅝ by 1¾.
100	250	4, 4½, 5-----	⅞ ₁₆	¾	¾ by 2¼-----	½	1¼ ₁₆	1¼ by 2¼.
100	250	2, 2½, 3-----	⅞ ₁₆	⅝	⅝ by 2¼-----	½	⅝	⅝ by 2¼.
250	400	4, 4½, 5-----	1⅞ ₁₆	2⅝ ₃₂	2⅝ ₃₂ by 2⅝-----	⅞ ₁₆	¾	¾ by 2¼.
250	400	2, 2½, 3-----	1⅞ ₁₆	¾	¾ by 2⅝-----	⅞ ₁₆	1¼ ₁₆	1¼ by 2¼.
400	600	2, 2½, 3-----	2⅝ ₃₂	2⅝ ₃₂	2⅝ ₃₂ by 2⅝-----	⅝	¾	¾ by 2¼.
600	1, 000	(See table IV)-----						

¹ When the inside depth of a box is 5 inches or less, end cleats shall not be used. Thickness of the ends shall be not less than the combined thickness of the end and cleat as specified for style 4 boxes, or if weight exceeds 400 pounds, as specified for style 2 boxes. Each side and end shall be made from one piece except when the end is approximately square, a two-piece end with each end piece of approximately equal thickness

and with the grain of each piece running at right angles to the other may be used. Two-piece ends shall be nailed together with no less than two nails clinched.

² If pieces ¾ inch or more in thickness are surfaced two sides, the thickness may be ¼ inch less than the thickness as determined from the table requirements.

CHAPTER 4

PRISONER-OF-WAR INCLOSURES

33. General

FM 27-10 sets forth the general provisions by which our forces will be governed in dealing with enemy personnel. TM 19-500 discusses the treatment and processing of prisoners of war and the security measures pertaining to them.

34. General Provisions

a. Prisoners of war must be lodged in buildings or barracks which are healthful, dry, heated, lighted, and protected from fire. Minimum dormitory area and air-space requirements will be the same as for troops at base camps.

b. Prisoners of war will have constantly at their disposal installations conforming to sanitary rules, including the best practicable provisions for baths and showers. They must be enabled to take physical exercise and enjoy the open air. Sexes must be segregated.

c. In a theater of operations, prisoners of war will be sheltered in existing facilities when possible. If facilities must be built, they will be of temporary construction. For economy in area and fencing, buildings are best grouped in the center of the inclosure and space between them and deadline fences used for open air and exercise.

d. Prisoner-of-war labor will be used to the maximum in establishing, converting, maintaining, and dismantling security and housing facilities for themselves and their guards. They will not receive wages for work connected with installing, maintaining, or administering the camps.

35. Security Provisions

a. Stockade fences (except high masonry walls or impassible terrain features) are temporary barriers only, to delay escape attempts and the entrance of unauthorized persons or contraband articles long enough to permit guards in towers or perimeter patrols to act.

b. Stockade fences of the following types are considered satisfactory:

- (1) A single chain-link woven steel-wire fence (2-inch mesh, 6- to 9-gage wire) not less than 8 feet high, with top 45° extension arms carrying three strands of barbed wire, and with barbed-wire concertinas anchored to the ground outside the fence.

- (2) Two fences of the above type set 8 to 10 feet apart, with barbed-wire concertinas fastened to the top of the outer fence.

c. The delaying effect of the stockade fence is substantially increased by installing a deadline fence (a barbed-wire fence about 3 feet high which prisoners of war are forbidden to cross) about 8 to 10 feet inside the inner stockade fence.

d. Normally one gateway for one-way vehicular traffic, with a wicket for pedestrians, is adequate.

e. Guard towers with lights are installed to improve observation and to permit enfilading fire along fences and streets and inside the stockade.

36. Sequence of Development

a. Prisoner-of-war inclosures are normally initiated in each army and task force service area, reverting to communications zone control and operation as the army rear boundary is advanced. Information for estimating the number likely to be captured is given in FM 101-10. Priority of other work in forward areas is likely to restrict construction, and initial prisoner-of-war inclosures will normally consist of existing buildings or tents for shelter, pit-type latrines, expedient facilities for cooking and bathing, and a stockade fence. Such facilities should be designed for full development later by prisoner-of-war labor.

b. Table 34 gives basic data on a prisoners-of-war camp for 1,000 men in a temperate climate, using tentage. Table 35 gives similar data for prefabricated or standard frame construction. Table 36 gives the key to coding of the construction standard (the code digit given being the second digit of the four-digit number identifying the type of installation).

Table 34

P.W. CAMP, 1,000 MAN, TEMPERATE CLIMATE,
STD 2, NEW CONST, TENTAGE (Site and Utility Dwg. 70-32).

Tentage NP-3.120

Provides inclosure and accommodations for 1,000 Prisoners
of War. All accommodations in tentage with earth floors.
Bucket type latrines in tentage.

Engineer Services Required:

Water—5,000 GPD.

Drainage—None.

Electrical Connected Load—None.

Facility	Size or unit	Basis	Facility No.	Number required	Material effort		
					ST	MT	MH
1 TENTAGE.....	57,856 SF.....	Tent Area.....	703292	1			
2 INTERIOR CONSTRUCTION.....					11	14	840
Latrine, Bucket Type, (tent) 12 seats.	16' by 32'.....	1 seat/20 men.....	723602	7	11	14	840
3 OTHER CONSTRUCTION.....					182	241	13, 580
Fence, Security, Type X.....	1,000 Ft.....		872102	13	104	156	7, 330
Fence, Security, Type Y.....	1,000 Ft.....		872103	1. 03	7	9	510
Fence, Security, Vehicle & Man Gate.	Each.....		872104	8	16	16	1, 410
Guard Tower.....	16' by 16'.....	1/cor & 1/600' fence.....	872301	8	44	44	1, 100
Guard Tower.....	16' by 24'.....	1/inclosure.....	872401	1	8	12	150
Road, 1 Lane, 4" Macadam.....	Mile.....	Installation Rds.....	851002	0. 04	0	0	80
Sentry Box.....	4' by 4'.....	1/main or comp. gate.....		4	0	0	0
Sump, Fire Protection.....	10,000 Gal.....	Effective radius 500'.....	843110	1	3	4	240
Site Preparation.....	Acre.....	100' outside perim.....	932000	23	0	0	2, 760
Total.....					193	255	14, 420

Table 35

P.W. CAMP, 1,000 MAN, TEMPERATE CLIMATE,
STD 3, NEW CONST, PREFAB or STD FRAME (Site and
Utility Dwg. 70-32).

PREFAB NP-3.131
STD FRAME NP-3.132

Provides inclosure and accommodations for 1,000 Prisoners
of War. Bathhouse, kitchen and latrine in buildings; all other
accommodations in tentage. Concrete floors: buildings and
tentage 2'', except Generator Bldg. 4''. Bucket type latrines.

Engineer Services Required:

Water—10,000 GPD.

Drainage—Open Ditch.

Electrical Connected Load—65.9 KW.

Facility	Size or unit	Basis	Facility No.	Number required	Material effort		
					ST	MT	MH
1 PREFAB BLDGS COMPLETE	8,700 SF	Phases 1 & 2	703201	1	39	113	950
Frame, Roof, & Foundation		Phase 1	703202	1	32	73	440
Cladding		Phase 2	703203	1	7	40	510
2 STD FRAME BLDGS COMPLETE	8,700 SF	Phases 1 & 2	703205	1	77	149	3,330
Frame, Roof, & Foundation		Phase 1	703206	1	52	115	2,670
Cladding		Phase 2	703207	1	25	34	660
3 TENTAGE	49,152 SF	Tent Area	703292	1			
4 FLOORS		Phase 3			109	109	1,280
Concrete, 2''	1,000 SF		342452	57.5	108	108	1,250
Concrete, 4''	1,000 SF		342454	.4	1	1	30

Table 35—Continued

Facility	Size or unit	Basis	Facility No.	Number required	Material effort		
					ST	MT	MH
5 INTERIOR CONSTRUCTION					45	91	3, 680
Bathhouse, 24 Shower Heads	20' by 50'	1 sh hd/24 men	723401	2	14	28	1, 240
Generator Bldg., 3-30 KW. Units	20' by 20'	1/installation	811203	1	11	25	260
Kitchen, 500 Man	40' by 60'	3 SF/man	726201	2	14	28	1, 560
Latrine, Bucket Type, 12 Seats	10' by 30'	1 seat/20 men	723601	5	6	10	620
6 OTHER CONSTRUCTION					263	408	21, 630
Fence, Security, Type W	1,000 Ft		872101	1. 97	18	28	1, 540
Fence, Security, Type X	1,000 Ft		872102	11. 0	88	132	6, 160
Fence, Security, Type Y	1,000 Ft		872103	1. 03	7	9	510
Fence, Security, Vehicle, & Man Gate.	Each		872104	8	16	16	1, 410
Guard Tower	16' by 16'	1/cor & 1/600' fence	872301	8	44	44	1, 100
Guard Tower	16' by 24'	1/inclosure	872401	1	8	12	150
Road, 1 Lane, 4" Macadam	Mile	Installation Rds	851002	0. 04	0	0	80
Sentry Box	4' by 4'	1/main or comp gate		4	0	0	0
Sump, Fire Protection	10,000 Gal	Effective radius 500'	843110	1	3	4	240
Utilities:							
Water distribution	Util Dwg	10 GPD/man	703210	1	11	17	1, 780
Drainage	Util Dwg	Waste water ditch	703211	1	1	1	190
Electric Distribution	Util Dwg	Light	703212	1	67	145	5, 710
Site Preparation	Acre	100' outside perimeter	932000	23	0	0	2, 760

Totals for Prefab Erection (1, 4, 5, & 6).					456	721	27, 540
Totals for Std Frame Erection (2, 4, 5, & 6).					494	757	29, 920

Table 36. Coding of Construction Standards

Code digit	Standard of construction
1	1 TOE tents; no engineer materials or effort involved.
2	2 Class IV tents pitched by using troops; engineer effort for roads and site preparation.
3	3 Buildings with floors for administration, bathhouses, infirmaries, storehouses, and kitchens. Class IV tents with floors for housing and with earth floors for all other purposes. Roads within the installations are stabilized with local materials. Water piped from central storage tank to infirmaries, bathhouses, and kitchens. Electric distribution to buildings. Pit type latrines.
4	4 Buildings with floors for all purposes except housing; Class IV tents with floors and wood frames for housing; roads within the installations are stabilized with local materials; water piped from central storage tank to infirmaries, bathhouses, kitchens, and camp exchange; electric distribution to buildings and tent housing. Pit type latrines.
5	5 Buildings with floors for all purposes. Roads, water supply, and latrines are the same as type 4 above; electric distribution to all buildings.
6	6 Buildings with floors for all purposes; latrines equipped with untreated sewage carried 1,000 feet beyond the confines of the camp; bituminous surfacing of roads within the installations; water piped from central storage tank to infirmary, bathhouses, latrines, kitchens, and camp exchange; electric distribution to all buildings.

CHAPTER 5

FORTIFICATIONS AND CAMOUFLAGE

Section I. GENERAL

37. General

Priority of work and data on clearing, on hand excavating for earth-works, and on minefields and barbed-wire entanglements are given in FM's 5-15, 5-34, and 101-10. Land-mine warfare is covered in FM 20-32. FM 101-10 includes estimating data for roadblocks and other antimechanized defense measures, as well as data on fordable depths of water and carrying capacity of ice. Permanent bomb-resistant structures are covered in TM 5-310. FM 5-20, 5-21, FM 5-22, and AFM 200-43 deal with camouflage.

38. Frontages Held by Units in Defense

Average frontages normally assigned to infantry or engineer units in defensive missions are given in table 37.

Table 37. Defense Frontages (in yards)

SITUATION					
Unit	Branch	Non-nuclear	Active nuclear		
Battle group---	Infantry-----	2, 500-4, 500	4,000-6,000 (no mobility); 7,000 (calculated risk); 9,000 (motorized or mechanized).		
ALL SITUATIONS					
Rifle company	Infantry	1 platoon	2 platoons	3 platoons	4 platoons
Close terrain---	Occupies-----	300	600	900	1, 200
	Occupies and covers---	500	1, 000	1, 500	2, 000
Open terrain---	Occupies-----	450	900	1, 400	1, 800
	Occupies and covers---	800	1, 600	2, 400	3, 000

Section II. COVER AND SHELTER

39. General

a. Requirements. Shelters are constructed primarily to protect troops from enemy action and the weather. They are not fighting emplacements but are often included in fighting positions. Shelters should be sited on reverse slopes, in woods, or in some form of natural defilade such as ravines, valleys, or depressions. All shelters must be camouflaged or concealed.

b. Types. Shelters are divided into two groups according to their type of construction—hasty or deliberate.

- (1) Hasty shelters are normally constructed of local, expedient materials by combat troops, primarily for protection from inclement weather when on short halts and bivouacs.
- (2) Deliberate shelters are constructed by supporting units in rear of frontlines for protection from artillery fire, strafing, bombing, and the weather.
- (3) Shelters, whether hasty or deliberate, are further divided into three general types—
 - (a) Surface shelters built aboveground where ground conditions prohibit excavation.
 - (b) Cut-and-cover shelters partially or wholly dug into the ground and backfilled and covered with soil.
 - (c) Cave shelters dug laterally into reverse slopes or tunneled into flat ground.

40. Protection Against Conventional Weapons

a. Table 38 shows the thicknesses of various materials required to protect against single direct hits by direct-fire weapons.

b. Table 39 shows the thicknesses of various materials required to protect against projectiles and bombs exploding at a distance of 50 feet.

Table 38. *Material Thicknesses Needed for Protection Against Direct Hits by Direct-Fire Weapons*

Material	Small-arms and machine-gun (7.92-mm.) fire at 100 yd. ¹ (Inches)	Antitank rifle (7.92-mm.) fire at 100 yd. (Inches)	20-mm. antitank fire at 200 yd. (Inches)	37-mm. antitank fire at 400 yd. (Inches)	50-mm. antitank fire at 400 yd. (Inches)	75-mm. direct fire, 500 to 1,000 yd. (Inches)	88-mm. direct fire, 500 to 1,000 yd. (Inches)	Remarks
Solid walls: ²								
Brick masonry-----	18	24	30	60				Plain, formed-concrete walls.
Concrete, not reinforced. ³	12	18	24	42	48	54	78	
Concrete, reinforced-----	6	12	18	36	42	48	78	
Stone masonry-----	12	18	30	42	54	60		Structurally reinforced.
Wood-----	24	36	48					These figures can be taken as guides only.
Timber-----	36	60						These figures can be taken as guides only.
Walls of loose material packed between boards: ²								
Brick rubble-----	12	24	30	60	72			Add 100 percent if wet. Add 50 percent if wet.
Clay, dry-----	36	48						
Loam, dry-----	24	36	48					
Gravel or small crushed rock.	12	24	30	60	72			Add 100 percent if wet.
Sand, dry-----	12	24	30	60	72			
Sandbags filled with:								
Brick rubble-----	20	30	30	60	70			Add 100 percent if wet. Add 50 percent if wet.
Clay, dry-----	40	60						
Loam, dry-----	30	50	60					

See footnotes at end of table.

Table 38. *Material Thicknesses Needed for Protection Against Direct Hits by Direct-Fire Weapons—Continued*

Material	Small-arms and machine-gun (7.92-mm.) fire at 100 yd. ¹ (inches)	Antitank rifle (7.92-mm.) fire at 100 yd. (inches)	20-mm. antitank fire at 200 yd. (inches)	37-mm. antitank fire at 400 yd. (inches)	50-mm. antitank fire at 400 yd. (inches)	75-mm. direct fire, 500 to 1,000 yd. (inches)	88-mm. direct fire, 500 to 1,000 yd. (inches)	Remarks
Sandbags filled with—Con.								
Gravel or small crushed rock.	20	30	30	60	70	-----	-----	
Sand, dry-----	20	30	30	60	70	-----	-----	Add 100 percent if wet.
Loose parapets of: ²								
Clay-----	42	60	-----	-----	-----	-----	-----	Add 100 percent if wet.
Loam-----	36	48	60	-----	-----	-----	-----	Add 50 percent if wet.
Sand-----	24	36	48	-----	-----	-----	-----	Add 100 percent if wet.

¹ 1 burst of 5 shots.² Thicknesses given to nearest half foot.³ For 3,000 p.s.i. concrete.

Protective thicknesses given are for a single shot only (except ¹). Where direct-fire weapons are able to get 5 or 6 hits in the same area, the required protective thickness is approximately twice that indicated.

Table 39. Material Thicknesses Needed for Protection Against Projectiles and Bombs Exploding 50 Feet Away

High-explosive shells and rockets				General-purpose bombs			
Material	75-mm. (inches)	105-mm. (inches)	155-mm. (inches)	100-lb. (inches)	250-lb. (inches)	500-lb. (inches)	1,000-lb. (inches)
Solid walls:							
Brick masonry-----	4	6	8	8	10	13	17
Concrete, plain-----	4	5	6	8	10	15	18
Concrete, reinforced-----	3	4	5	7	9	12	15
Timber-----	8	10	14	15	18	24	30
Walls of loose material between boards:							
Brick rubble-----	9	10	12	18	24	28	30
Gravel, small stones-----	9	10	12	18	24	28	30
Earth ¹ -----	15	18	24	24	30	-----	-----
Sandbags filled with:							
Brick rubble-----	10	10	20	20	20	30	40
Gravel, small stones-----	10	10	20	20	20	30	40
Sand ¹ -----	10	10	20	30	30	40	40
Earth ¹ -----	20	20	30	30	40	40	50
Parapets of: ²							
Sand ¹ -----	12	18	24	24	36	36	48
Earth ¹ -----	24	36	48	36	48	60	-----

¹ Figures based on dry material. If wet material, double figures.

² Figures given to nearest ½ foot.

41. Ice and Snow: Classification

The following terms and criteria are used to describe snow conditions.

a. Grain Nature.

- (1) New snow (original crystal forms).
- (2) Old snow (granular).
 - (a) Fine-grained like table salt.
 - (b) Coarse-grained like coarse sand.

b. Hardness. (Use mitten or glove.)

- (1) Soft (mitten tip or four fingers).
- (2) Medium hard (mitten thumb or one finger).¹
- (3) Hard (pencil).¹
- (4) Very hard (knife).¹

c. Wetness. (Use mittens or gloves.)

- (1) Dry (snowball cannot be made).
- (2) Moist (does not contain water, but snowball can be made).
- (3) Wet (liquid water can be pressed out).
- (4) Slushy (mixture of snow and liquid water).

¹ The object indicated (but not the foregoing one) can be pushed into the snow without considerable effort.

d. Surface and Profile Conditions. When appropriate, surface and profile conditions may be described in connection with the above classification. For example, in describing a snow profile the thickness of visually distinguishable layers and their sequence can be measured and the snow type of each layer indicated by the above classification. Drifted snow of granule form is always considered as old snow even if freshly deposited.

e. Examples.

- (1) New snow, dry and medium hard.
- (2) Fine-grained old snow, moist and hard.
- (3) Thirty inches of fine-grained old snow, dry and very hard, covered by six inches of new snow, soft and dry.
- (4) Six-inch crust of fine-grained old snow over six inches of drifted snow, medium hard and dry.
- (5) Six inches of coarse-grained old snow, soft and slushy.

42. Ice and Snow Cover

Minimum thicknesses of snow and ice for protection against small-arms fire are as follows:

New snow, 13 feet.

Tamped snow, 8 to 10 feet.

Frozen snow, 6.5 feet.

Ice, 3.25 feet.

Ice concrete, 1 to 2 feet.

43. Ice Concrete

Ice concrete is a dense frozen mixture of sand and water, or sand with gravel and crushed rock and water. At least 10 percent of the mixture should be sand and only enough water should be added to the mixture to make it slightly liquid. A sheet of this material, 4 inches thick, will freeze solid in 4 to 6 hours at -13° F. In fortification construction it is used for overhead cover, parapets, breastworks, or sandbag filler.

44. Protection Against Nuclear Weapons

See FM 101-31, FM 101-31A, TM 5-311, TM 23-200, DA Pam 39-1, and DA Pam 39-3.

Section III. OBSTACLES

45. Planning and Construction of Obstacles

Normal obstacle planning accomplished in divisional and larger units is summarized in table 40. Table 41 is an obstacle planning checklist for unit engineers, and table 42 shows obstacle construction data.

Table 40. Obstacle Planning Responsibilities

Command	Pertinent points of commander's plans
Army-----	(1) Broad barrier plan for army area, including key bands. (2) Assignment of tasks to subordinate units. Covering forces construct covering barriers, and security forces on open flanks erect flank barriers. Army and corps troops install rear-area and flank barriers. (3) Limitations on use of obstacles in any particular area to insure coordination with general plans. (4) Emphasis on need for secrecy. Precautions must be taken to safeguard charts and maintain security of barrier plan. Broad plan should not go below division.
Corps-----	(1) Detailed barrier plan for corps area, made from map study, covering: (a) Location of natural and artificial barriers, including major minefields; (b) Location of lanes to be left open for counter-attack plans and supply. (2) Assignment of tasks to subordinate units including division and corps troops. (3) Close coordination of division plans. (4) Detailed siting of corps flank barriers. (5) Maps or overlays showing plan in enough detail so lower units will know exactly which barrier lines are to be installed or reinforced.
Division--	Based on corps master plan: (1) Plan of bands or zones of obstacles and purpose each is to serve. (2) Timetable and priority of construction. (3) Demolition orders. (4) Routes to be kept open in accordance with tactical plan. (5) Need for secrecy. Detailed plan should not be in hands of front-line units. (6) Limitations on use of chemical agents. (7) Assignment of troops and equipment for construction and defense.

Table 41. Engineer Obstacle Planning

Plan phases	Phase details	Source of information
Map study-----	(1) Analyze all natural obstacles useful to mission of unit----- (2) Locate gaps and defiles in natural obstacles.	Maps, aerial photographs.
Reconnaissance-----	(1) Locate individual obstacles from actual reconnaissance of terrain and determine effectiveness of each obstacle. (2) Determine type of artificial obstacle to use at each location or amount of work necessary to reinforce natural obstacle. (3) Estimate time, labor, and materials needed for each obstacle.	Engineer reconnaissance patrols, personal reconnaissance, combat patrols, and civilians.
General plans-----	(1) Indicate plan on map in graphic form showing location of each obstacle band and principal types of obstacles in band. (2) Prepare table of priority of construction, including time, labor, and material estimates. (3) Submit final plan for approval and coordination with tactical plan of unit commander.	Previous reconnaissance and map study, and orders from higher authorities.
Detailed plans-----	(1) Prepare detailed plans and orders----- (2) Subdivide work, assign tasks to units, and issue orders.	Previous reconnaissance and map study.
Report-----	Submit report of completed obstacles to next higher commander.	

Table 42. Obstacle Construction Data

Obstacle	Construction method	Normal employment	Construction rate
Antitank ditch-----	By multiple-charge method— 10 ft. deep----- 30 ft. wide-----	(1) For permanent system of fortifications: Construct across wide avenues of approach. (2) For hasty or temporary fortifications. Construct across only short distances—25 to 50 ft.	1 squad with power earth auger and demolition equipment can complete 100 yds. in 12 hr.
	By hand tools— 6 ft. deep----- 12 ft. wide-----		One platoon under average conditions can do 100 ft. of triangular ditch in 7½ hr., and 100 ft. of trapezoidal ditch in 14 hr.
	Using ¾-yd. shovel with 2 operators and 3 to 10 finishers.		Platoon can dig 100 ft. of triangular ditch in 4½ hr. and 100 ft. of trapezoidal ditch in 9 hr.
Log post obstacle-----	Substantial posts set in the ground, density of 1 post per linear foot, 2½- to 3½-ft. projection.		1 squad with pile driver can complete 50 ft. in 1 day under average conditions.
Contamination by persistent chemicals (when authorized).	Contaminate artificial obstacles to impede removal. Contaminate roads and areas as part of a barrier mission.	1 or more chemical mines per obstacle. 200 mines per mile of road, or—Airplane spray: Average area covered by 1 airplane— 80 yd. long 300 yd. wide	1 squad can contaminate 1 mile of road in 1½ hr.

46. Minefields

a. The various types of minefields are as follows:

- (1) *Protective minefields*, used for the close-in protection of small units in forward combat areas and units or installations in rear areas if infiltration, raiding, or sabotage is a threat.
- (2) *Defensive minefields*, used as an element in the defense of organized and occupied tactical localities within a battle position.
- (3) *Barrier minefields*, used to block an enemy attack in certain areas and to canalize his advance into other selected areas.
- (4) *Nuisance minefields*, used to delay and disorganize the enemy and hinder his use of a certain area or route.
- (5) *Phony minefields*, used to make the enemy think that an area has been mined.

b. Logistical data on antitank and antipersonnel mines are shown in table 43. Table 44 shows data on minefield clearing with explosive devices. The weights and explosive contents of certain American and foreign mines are given in paragraph 210. For further details, see FM 5-25, FM 20-32, and TM 9-1946.

Table 43. Logistical Mine Data Table

Note: Figures in parentheses indicate maximum load w/in 100 percent overhead capability &/or maximum volume of cargo space

Mine model & type	Weight (lb.) per mine	Mine packaging data					Capacity of indicated army vehicles				
		Number of mines, etc., per crate	Wt (lb.) per crate	Craft dimensions (in.)			M-35 2½-ton cargo truck (cargo space: 147 by 88 by 60 in.)				
				Length	Width	Height	Number of crates	How carried	Number of types of crates	Total number mines	Total weight (tons)
M-7 AV-----	5. 0	a. 8, w/fuzes----	56	19. 25	11	8. 25	90 (178)	Flat-----	2 (4)	720 (1, 424)	2. 52 (4. 98)
		b. 12, w/fuzes---	71. 5	23. 5	11. 75	9. 5	70 (140)	Flat-----	2 (4)	840 (1, 680)	2. 5 (5)
M-6 AT-----	20. 0	a. uncrated mines.	13.13 in. diam---	-----	-----	3. 25	-----	Flat-----	4	250 (264)	2. 5 (2. 64)
		b. 1, w/fuze & activ.	31	13. 5	13. 5	3. 75	162 (322)	On end (flat)	1 (6)	162 (322)	2. 51 (4. 99)
		c. 2, w/fuzes & activ.	60	18. 13	16	9. 75	84 (160)	Flat-----	2 (4)	168 (320)	2. 52 (4. 8)
M-15-----	30. 0	a. uncrated mines.	-----	13.13 in. diam---	-----	5	-----	Flat (flat, 11 on end).	3— (3)	166 (209)	2. 49 (3. 13)
		b. 1, w/fuze & activ.	49	18	15. 13	7. 5	103 (200)	Flat-----	3 (5)	103 (200)	2. 53 (4. 9)

Table 43. Logistical Mine Data Table—Continued

Mine model & type	Weight (lb.) per mine	Mine packaging data					Capacity of indicated army vehicles				
		Number of mines, etc.,	Wt (lb.) per crate	Craft dimensions (in.)			M-35 2½-ton cargo truck (cargo space: 147 by 88 by 60 in.)				
				Length	Width	Height	Number of crates	How carried	Number of types of crates	Total num- ber mines	Total weight (tons)
M-19 AT-----	28.0	2, w/fuzes & activ.	80	16.25	10.5	16	63 (125)	On end (on side)	1 (3)	126 (250)	2.52 (5)
T29 AT-----	15.0	2, w/T-1200 fuzes.	50.3	26.5	11	7.33	100 (198)	On end (flat).	1 (5)	200 (396)	2.51 (4.97)
M-2 AP-----	5.0	6, w/fuzes & wire.	50	15	10.25	9.5	100 (200)	Flat-----	2 (3)	600 (1,200)	2.5 (5)
M-3 AP-----	9.6	6, w/fuzes & wire.	72	18	8.75	9.5	70 (138)	Flat-----	2— (2+)	420 (828)	2.52 (4.96)
M-16 AP-----	8.0	4, w/fuzes & wire.	45	15.75	10.13	8.5	112 (222)	Flat-----	2 (4)	448 (888)	2.52 (4.99)
M-18 AP-----	2.5	a. 6(M-68 Kit)	33.1	20	11.5	9.75	151 (294)	Flat-----	4 (6)	905 (1,764)	2.49 (4.87)
		b. 10 (M-69 Kit).	45	14.25	15	17.25	112 (162)	Flat-----	2+ (3)	1,120 (1,620)	2.52 (3.64)

M-14 AP-----	0. 2	90, w/dets. & wrenches.	44	19	18	8. 75	114 (227)	Flat (on end).	4 3	10, 260 (20, 430)	2. 5 (4. 99)
E-5 chem-----	24. 7	3, w/fuzes & activ.	a. 110 (1 drum)	17.5 in. diam. (standard shipping drum).		22	46 (80)	On side (on end).	2 (2)	138 (240)	2. 53 (4. 4)
			b. 1,840 (pallet of 16 drums)	52	46	48	3 pallets.	Flat-----	1	144	2. 76
M-48 Parachute Flare.	5. 0	4, w/fuzes & wire.	41. 0	14. 7	13. 13	11	122 (244)	Flat-----	2+ (4+)	488 (976)	2. 5 (5)
M-49 Static Flare.	1. 4	a. 16, w/fuzes & wire.	44. 9	21. 25	14. 5	11	111 (180)	Flat-----	3+ (5)	1, 776 (2, 880)	2. 49 (4. 04)
		b. 25, w/fuzes & wire.	59	21. 25	14. 5	11	84 (170)	Flat-----	3- (5)	2, 100 (4, 250)	2. 47 (5)

Table 43. Logistical Mine Data Table—Continued

Mine model & type	M-105 1½-ton trailer (cargo space: 133 by 87 by 71 in.)					M-47 2½-ton dump truck (cargo space: 108 by 70 by 15 in.) (Volume is determining factor)				
	Number of crates	How carried	Number of tiers of crates	Total number of mines	Total weight (tons)	Determine number of crates	Capacity how carried	Number of tiers of crates	Total number mines	Total weight (tons)
M-7 AV-----	56 (110)	Flat-----	2 (3)	448 (880)	1. 56 (3. 08)	72-----	On end-----	1	576	2. 01
	41 (85)	Flat (on end)---	2 (1)	492 (1, 020)	1. 46 (3. 02)	63-----	On end-----	1	756	2. 25
M-6 AT-----		Flat (on edge)---	3 (2)	150 (300)	1. 5 (3)	-----	On edge-----	1	165	1. 65
	96 (195)	Flat-----	2 (4)	96 (195)	1. 48 (3. 02)	140-----	On end-----	1	140	2. 17
	50 (100)	Flat-----	2 (4—)	100 (200)	1. 5 (3)	42-----	On end-----	1	84	1. 26
M-15-----		Flat (on edge)---	3 (2)	100 (200)	1. 5 (3)	-----	On edge (or flat).	1 (3)	105	1. 57
	51 (122)	Flat-----	2 4	61 (122)	1. 49 (2. 98)	56-----	On end-----	1	56	1. 37
M-19 AT-----	37 (75)	Flat-----	1— 2	74 (150)	1. 48 (3)	40-----	On end-----	1	80	1. 6
T29 AT-----	59 (119)	Flat-----	2 (4—)	118 (238)	1. 49 (2. 99)	81-----	On end-----	1	162	2. 03

M-2 AP	60 (120)	Flat	1 (2)	360 (740)	1. 5 (3)	70	On end (or flat).	1 (2)	420	1. 75
M-3 AP	41 (83)	Flat	1 (2—)	246 (498)	1. 47 (2. 98)	70	On end (or flat).	1— (2—)	420	2. 52
M-16 AP	66 (133)	Flat	1— (2+)	264 (532)	1. 48 (2. 99)	80	On end (or flat).	1 (2)	320	1. 80
M-18 AP	90 (181)	Flat	3— (5)	540 (1, 086)	1. 48 (2. 99)	63	On end	1	378	1. 04
	66 (133)	Flat	2 (3)	660 (1, 330)	1. 48 (2. 99)	28	Flat	1	280	. 48
M-14 AP	. 68 (136)	Flat	3 (5)	6, 120 (12, 240)	1. 49 (2. 99)	48	On end	1	4, 320	1. 05
E-5 chem	27 (54)	Flat	2— (3)	71 (142)	1. 48 (2. 97)	24	On end	1	72	1. 32
	2 pul- lets.	Flat	1	96	1. 84	2 pallets	Flat	1	96	1. 84
M-48 Parachute Flare.	73 (146)	Flat	2+ (3—)	292 (584)	1. 49 (2. 98)	70	Flat	2	280	1. 43
M-49 Static Flare.	66 (132)	Flat	2 (4—)	1, 056 (2, 112)	1. 48 (2. 96)	42	On end	1	672	. 94
	50 (101)	Flat	2 (3—)	1, 250 (2, 525)	1. 47 (2. 97)	42	On end	1	1. 050	1. 23

Table 44. Clearing and Breaching Minefields with Explosive Devices

Item	M3A1	Cable, detonating, mine-clearing, AP, M 1	Bangalore torpedo
Purpose.....	Breach AT minefield.....	Clear narrow lane in AP mine-field.	(¹).
Length.....	400 ft.....	170 ft.....	50 ft.
Weight.....	9,000 lb.....	63 lb.....	168 lb.
Weight of explosive.....	4,480 lb.....	46 lb.....	85 lb.
Metal used in case.....	Aluminum.....	Aluminum.....	Aluminum.
Crater produced:			
Length.....	320 ft.....	(²).....	56 ft.
Width.....	4-12 ft. or more.....	.....	(³).
Depth.....	2-4 ft. or more.....	.....	(³).
Usual width of mine clearance accomplished.....	10-15 ft.....	8 ft. or less ⁴	10 ft. or less. ¹

¹ The primary purpose of the bangalore torpedo is to clear a path through wire. It will destroy or detonate most AP and AT mines within 5 ft. of it.

² No clearly defined crater. Surface soil disturbed.

³ Shallow.

⁴ Mines directly under the cable will be destroyed or detonated. Pressure-type mines within 5 ft. of it may or may not be detonated.

47. Wire Entanglements

Quantities and estimating data for barbed-wire obstacles are given in FM 101-10 and FM 5-34. Fundamental principles used in locating them are summarized in table 45. Table 46 shows quantities and truckloads required per thousand yards of the various barbed-wire entanglements.

Table 45. Barbed-Wire Entanglement Principles

Type according to mission	Location	Depth	Siting requirements	Gaps
Tactical-----	Along friendly side of final protective line. Extend across front of a position but are not necessarily continuous.	1 belt minimum.	(1) Covered by fire. (2) Under observation and protected by antipersonnel mines and warning devices. ¹ (3) Avoid regular geometric layouts and easily disclosed positions. (4) Concealed from ground and air observation wherever possible by incorporation of natural features such as hedges, woods, paths, or fence lines. (5) Coordinated with other elements of the defense. (6) Use in sufficient quantity.	Leave gaps during erection to: (1) Provide passage for patrols or working parties. (2) Permit advance of attacking or counterattacking elements.
Protective-----	Close enough to defense area for day and night observation and far enough away to keep enemy beyond normal hand grenade range.			
Supplementary---	In regular lines in front of tactical wire and between mortar target areas; and to connect platoon and company defense areas.	1 belt-----	Added when time permits, to conceal exact location and direction of tactical wire.	

¹ When practicable and if authorized by the commander of a division or larger unit.

Table 46. Wire Loads.

Type	Tons	Measure- ment tons ¹	Truckloads	
			¾-ton	2½-ton
Double apron, 4 and 2 pace.....	5	6. 4	7	2
Double apron, 6 and 3 pace.....	3. 5	4. 5	5	2
High wire (less guy wires).....	6	7. 6	8	3
Low wire, 4 and 2 pace.....	3. 75	4. 75	5	2
4-strand fence.....	2	2. 54	3	1
Double-belt expedient concertina.....	7	8. 9	10	3
Triple-belt expedient concertina (pyramided).....	10. 5	13. 4	14	4
Triple-belt standard Dannert concertina.....	7. 5	9. 5	10	3

¹ Measurement ton 40 cubic feet.

Section IV. CAMOUFLAGE

48. Issue Camouflage Materials

Issue camouflage materials include cotton twine nets, both ungarnished and garnished with vegetable fiber burlap in flat-top or drape patterns; camouflage net sets of the drape type comprised of two or more garnished nets with ancillary components; wire netting which can be garnished with vegetable fiber, steel wool, paints, wire, wire rope, cotton twine, fiber rope, wood and metal stakes and supports; and several miscellaneous items.

49. Nets and Net Sets

a. Individual nets are issued ungarnished or garnished with vegetable fiber (burlap) in flat-top pattern or in drape pattern.

- (1) *Flattops*. A flattop consists of a twine net (wire for more permanent installations) that is stretched parallel with the ground and garnished with natural or artificial materials to blend with the surrounding terrain. A flattop should extend past the area to be concealed on each side by a distance equal to twice the height of the flattop above the ground. For complete concealment flattops should be no more than three feet above the general height of the vegetation at their edges.

- (2) *Drape nets*. Drape nets (individual) are pregarnished twine nets, designed to provide concealment for vehicles, artillery, and other similar equipment. They are issued in the following sizes (in feet):

17 by 35	29 by 29
22 by 22	36 by 44
29 by 14	45 by 45

Table 47. Characteristics of Camouflage Net Sets, Drape Type

Net set, drape	Size and number of nets	Total square feet	Weight (pounds)	Cubage (feet)	Packaging
72' by 88'-----	36' by 44' (4)-----	6,336	1,070.0	60.5	5 bags; 3 pole-carrying boxes.
58' by 58'-----	29' by 29' (4)-----	3,364	648.0	34.0	3 bags; 2 pole-carrying boxes.
44' by 44'-----	22' by 22' (4)-----	1,936	365.5	21.5	3 bags; 1 pole-carrying box.
34' by 35'-----	17' by 35' (2)-----	1,190	306.0	15.0	2 bags; 1 pole-carrying box.
28' by 29'-----	14' by 29' (2)-----	812	145.0	6.0	1 bag (nets). Ribs (loose).
90' by 90' (Basic set)-----	45' by 45' (4)-----	8,100	1,320.0	79.0	5 bags; 2 pole-carrying boxes; 3 heavy-duty pole-carrying cases.
With supplemental equipment 104' by 118'.	14' by 29' (12); 29' by 29' (2).	12,272	1,713.0	111.3	3 bags.
90' by 180'-----	45' by 45' (8)-----	16,200	2,483.0	151.0	2 pole-carrying boxes; 8 pole-carrying cases; 10 canvas carrying bags.

b. Camouflage nets garnished in drape pattern are also issued in sets. These sets contain two or more nets for assembly, garnished as a component to fit into the overall pattern of the set. Since these nets drape to the ground, they offer considerably better concealment than do the nets of the flattop pattern. Their principal characteristics are shown in table 47.

50. Garnishing Nets in the Field

a. Precolored cloth or cloth impregnated in the field is used to match garnished nets to local coloration. Percentages of colors usually required are shown in table 48.

Table 48. Color Percentages

Tropical and summer temperate	Winter temperate	Desert terrain	All seasonal
Dark green, 70 percent. Light green, 15 percent. Field drab, 15 percent.	Earth brown, 60 percent. Olive drab, 30 percent. Earth red, 10 percent.	Sand, 80 percent. Olive drab, 10 percent. Light green, 10 percent.	Dark green, 60 percent. Earth brown, 40 percent.

b. Materials and man-hours for garnishing twine net, mesh $2\frac{1}{4}$ inches square, are shown in table 49.

Table 49. Camouflage Materials and Man-Hours Required for Garnishing Twine Net

Size (feet)	Weight (pounds)		Cubage (cubic feet)		Number of garnishing strips 2" by 60"		Number of rolls 2" by 300'		Approximate man-hours	
	Flattop	Drape	Flattop	Drape	Flattop	Drape	Flattop	Drape	Flattop	Drape
15 by 15-----	9	11.8	0.9	1.18	234.0	306	4	5	5	7-8
14 by 29-----	12	15.8	1.0	1.31	422.0	550	7	9-10	14	19-20
22 by 22-----	15	19.6	1.5	1.96	454.0	594	8	9-10	14-15	19
17 by 35-----	20	26.2	2.0	2.6	617.0	808	10	13-14	19	25-26
29 by 29-----	27	35.2	3.3	4.3	874.6	1,142	14-15	19	30	40
36 by 44-----	51	66.9	5.0	6.6	1,645.0	2,160	27	36	55	60
45 by 45-----	60	78.5	6.0	7.9	2,110.0	2,760	35	46	60	62-63

51. Paints and Adhesives

Basic data for various types of paints and adhesives used for camouflage purposes are given in table 50 and stains used in the field are given in table 50.1. Supplementing this, table 51 gives data on tone-down materials for use on concrete, and table 52 gives data on adhesives used with granules. Table 52.1 gives the coverage data of paints and adhesives on certain types of materials. For further details see FM 5-22.

Table 50. Camouflage Paints and Adhesives

Type of material	How issued	Colors	How prepared	Drying time	Resultant surface
Paint, camouflage, resin oil emulsion and resin emulsion type paste.	Ready-mixed	FED SPEC TT-C-295.	Mix with water or mineral spirits.	About 24 hours.	Flat finish.
Paint, camouflage, emulsifiable.	Paste-----	Standard camouflage colors.	Mix with water or organic solvents.	On wood or metal, not over 6 hours.	Flat and lusterless.
Paint, protein-binder, cold water.	Powder-----	FED SPEC TT-C-295.	Mix with water-----	48 hours to be slightly rain resistant; can handle in 6 hours.	Hard, flat surface.
Paint, paste, lusterless, gasoline removable.	Paste-----	White, in engr. depots; commercial, all colors.	Mix with gasoline or mineral spirits.	15 to 60 minutes.	Flat.
Cement water paints-----	Powder, cement; protein powder, modified cement; and oil paste, modified cement.	A range of light colors.	Mix with water-----	30 minutes to 6 hours.	Hard, opaque, flat, lusterless.
Oil-type paints for runways.	Ready-mixed-----	White and yellow--	Ready for application; can thin with mineral spirits or turpentine.	Less than 1 hour.	Flat (must be specified).
Paint, camouflage, bituminous emulsion, adhesive.	Ready-mixed-----	Dries to a blackish brown.	Mixed with water. For better penetration, add wetting agent.	To touch, 8 hours.	Medium gloss; dulls rapidly on exposure.

Cutback asphalt-----	Slow cure, medium cure, rapid cure.	Dark brown to black.	Slow cure, diesel oil; inedium cure, kerosene; rapid cure, gasoline.	Variable, but quick drying.	Mat.
Primer, enamel undercoater, phenolic.	Ready-mixed-----	Dull red, yellow---	Stir with paddle-----	Enough to recoat, 24 hours.	Dull, opaque film.
Camouflage face paint-----	Stick form-----	White troops, light green and loam. Colored, light green and sand.	Ready for use-----	-----	
Stains for wood surfaces-----	3 types, all ready-mixed.	Varies with manufacturer.	Ready for use; can thin with mineral spirits or turpentine.	8-12 hours-----	Flat.
Field-expedient tentage stain No. 1.	Field expedient-----	Dark gray-----	Mix with earth, GI or field expedient soap, soot, and paraffin, as directed.	Variable, fairly rapid.	Flat, lusterless.
Field-expedient tentage stain No. 2.	Field expedient-----	Dark gray-----	Mix with charcoal and water as directed.	-----	Mat finish.
Fabric dye-----	Both liquid and powder.	Various-----	Mix with salt and water and use as directed.	At least 2 hours.	
Paint, emulsified, field expedient.	Field expedient-----	Depends on range of earth colors available.	Mix, as directed, crankcase oil salvage or waste, water, and pigmented soil with: (Type I) ground clay or powdered carbon and gasoline; or (Type II) GI or field expedient soap and clay or diatomaceous earth.	-----	

Table 50. Camouflage Paints Adhesives—Continued

Type of material	How issued	Colors	How prepared	Drying time	Resultant surface
Field expedient soap (for field expedient paint).	Field expedient		Mix and treat, as directed, waste kitchen grease and wood ashes.		
Raw molasses (for field expedient paint).	Liquid	Brown	Thin with water	Always sticky	
Used crankcase oil	Salvage	Brownish	Use as supplied or mix with native colored earths.		
Asphalt cement	Commercial				
Canvas refinishing compound.	Ready-mixed	Dark O.D., O.D., or green. Major unit commanders may requisition other colors.	Stir; dilute with gasoline if needed.	At least 2 hours	Mat finish.
Field expedient green vegetation adhesive.	Practically any green vegetation.		Boil fresh-cut plant material in water and treat as directed.		
Field expedient starch adhesive.	Any food containing starch, such as flour, grains, potatoes, etc.		Prepare from raw materials as directed.		
Glue-paste adhesive	Field expedient		Combine, as directed, flour paste, glue sizing, resin-sizing, varnish, borax, and hot water.		

Table 50.1. Field Expedient Stains

Type	Color	Source	Use	How prepared	Application	Drying time	Finish	Removal	Climate limitations	Durability
Tent Stain #1.	Dark gray.	Manufacture by troops.	Tentage----	Mix ½ lb soap with 8 gals water. Add enough paraffin soaked soot to get the desired color.	Brushing, Swabbing.	Rapid--	Flat---	Not practical.	Not recommended for freezing temperatures.	Fair.
Tent Stain #2.	Dark gray.	Manufacture by troops.	Faded or undyed tents.	Mix charcoal with water to desired shade.	Swabbing---	Rapid--	Flat---	Not practical.	Not recommended for freezing temperatures.	Good.
Used crankcase oil.	Brown	Motor pools, air bases.	To tone down concrete, stabilized soil, soil around emplacements.	Ready for application.	Spreading---	N/A---	N/A---	N/A-----	None-----	Fair.
Asphalt cement.	N/A---	Commercial.	Staining concrete or bituminous surface.	Ready mixed.	Brushing, Pressure distributor.	30 minutes.	Rough-	N/A-----	45° F. limit for application.	Good.

Table 51. *Tone-down Materials For Use on Concrete*

Coating material	Container	Colors	Source	Durability	Preparation	Drying time (hours)	Climate limitations	Application
Cutback asphalt (coal tar may be substituted).	55 gal. drums.	Brownish-black.	Commercial, ¹ Fed. Spec. SS-A671.	Good-----	Ready mixed: quick-dry, medium-dry, slow-dry.	(Med) 24	Requires dry surface and conditions. May be used at subfreezing temp.	Brushing; spraying—hand or pressure.
Coating compound, bituminous emulsion	55 gal. drums.	Brownish-black.	Commercial, ¹ MIL-P-3840.	Good-----	Ready mixed--	48	Can be applied to damp surface. Temperature must be above 45° F. Not good in tropics.	Brushing; pressure spraying.
Paint, water, paste.	5 gal. can.	All camouflage colors.	Commercial, ¹ MIL-P-13340.	Fair-----	Must be thinned w/gasoline or water, 1 to 1 by volume. Use gas or naphtha below freezing.	6	Can be applied to damp surface. Good between -40° and +160° F.	Brushing; pressure spraying.

Pigmented sodium silicate.	Varies----	All camouflage colors.	Commercial. ¹	Good on rough surface, poor on smooth.	Concentrate thinned w/water is sprayed on surface followed by spraying with calcium chloride to set or fix.	N/A	Can be applied to damp surface.	Pressure spraying.
Paint, traffic.	1 gal. cans.	White-----	TT-P-115A--	Excellent for traffic surface.	Ready mixed.	1	Dry, clean surface required.	Pressure spraying.
Xylene and tar (Rt. 2). Kerosene and asphalt (similar to British pitch and creosote mix).	Varies----	Brownish-black.	Commercial. ¹	Fair-----	Mix 80 tar to 0.20 xylene. Mix 25 asphalt to 75 kerosene by volume.	Rapid----	Dry, clean surface required.	Spraying—hand and pressure.

¹ Material has no specification, is made up in camouflage colors commercially.

Table 51. *Tone-Down Materials For Use on Concrete*—Continued

Coating material	Coverage (square feet per gallon)	Thinners	Fire hazards during application	Effects of jet exhaust at warmup points	Suitable texturing materials	Remarks
Cutback asphalt (coal tar may be substituted).	25 to 90-----	Quick-gasoline; medium-kerosene; slow-diesel fuel.	High. If coating is heavy will support combustion if fired by jet exhaust or other means.	Melting increases shininess and slipperiness. Possible fire.	Gravel; slate chips. Wood chips if time is not a factor.	Not recommended for surface exposed to jet exhaust.
Coating compound, bituminous emulsion.	25 to 90-----	None-----	Low-----	Will remove. Better than cutback asphalt but has similar drawbacks.	Asphalt chips, rubber chips, wood chips, other small granules.	Surfaces coated cannot later be painted with lasting success with any other type paint.
Paint, water, paste.	450 to 600----	Water, gasoline, and naphtha.	High when gasoline and naphtha are used. Low with water.	Will remove but will not support its own combustion.	None-----	None.

Pigmented sodium silicate.	Not available.	Water-----	None-----	Not available----	None-----	Good for limited types of surface. Traffic on smooth surface pulverizes brittle coating which then blows away or washes off.
Paint, traffic----	300 to 350----	Turpentine, gasoline, naphtha.	Medium to high.	Will blister and change color.	None-----	Best but costly.
Xylene and tar (Rt. 2). Kerosene and asphalt (similar to British pitch and creosote mix).	Not available.	Xylene, kerosene--	High-----	Will remove. No fire hazard with thin film, may be with thick film.	None-----	Primarily a cheap stain. Has application and fire drawbacks.

Table 52. *Texturing Materials*

Texturing materials	Durability compared with rock chips (percent)	Abrasion	Coverage per ton in square yards	Sources
Wood chips 1"-----	75	Low-----	800	Tanneries, wood pulp concerns, paper mills.
Rock chips ½"-----	100	High-----	90	Quarries and road building contractors.
Gravel-----	100	Medium--	90	Gravel pits.
Leather chips-----	75	Low-----	115	Shoe and leather goods manufacturers.
Coffee beans-----	75	Low-----	90	Coffee growers.
Wood cubes-----	60	Low-----	161	Lumber (cubes made on site).
Fabric (burlap scraps or similar materials).	30	Low-----	2, 000	Rag and textile concerns.
Plant mix, 1¼" open graded aggregate.	100	Medium--	22	Asphalt distributors.
Slag-----	80	High-----	90	Iron and steel blast furnaces.
Pine bough tips-----	20	Low-----	400	Local labor.
Pine cones-----	20	Low-----	161	Local labor.
Excelsior-----	30	Low-----	2, 000	Wood-pulp concerns.
Shredded coconut fiber (coir).	15	Low-----	2, 000	Byproduct of cocoa manufacturing.
Redwood fiber-----	30	Low-----	1, 600	
Cinders-----	90	High-----	90	R.R. roundhouses, boilers, factories.
Feathers-----	15	Low-----	20, 000	Poultry slaughterhouses, mattress manufacturers.
Cottonseed hulls-----	50	Low-----	3, 000	Cotton gins.
Spanish moss-----	10	Low-----	2, 000	Local labor.
Paper, shredded-----	. 05	Low-----	2, 000	Paper mills, junk dealers.
Sawdust, ⅓"-----	75	Low-----	3, 000	Lumber mills, furniture manufacturers, plywood mills.
Tin cans-----				Salvage depots.
Leaves and chopped palm fronds.	15	Low-----	2, 000	Local labor.
Seaweed-----	10	Low-----	2, 000	Local labor.

Note. These figures are approximate, for purpose of comparison and rough estimates.

Table 52.1. Coverage Data

Coating material	Asphalt, macadam, bituminous surfaces, tar-coated roofing paper					Concrete, stucco, brick, building stone, slate				
	Brushing		Spraying			Brushing		Spraying		
	Square feet per gallon	Man-hours per 100 square feet	Square feet per gallon	Sprayer (square feet per hour)	Pressure distributor (square feet per minute)	Square feet per gallon	Man-hours per 100 square feet	Square feet per gallon	Sprayer (square feet per hour)	Pressure distributor (square feet per minute)
Paint, water, paste MIL-P-13340 (table I) -----	450	1	600	3,000	N/A	400	1	500	3,000	N/A
Xylene and tar (R-2); kerosene and asphalt (table II) -----						200	1	200	2,040	6,000
Paint, temporary, paste, MIL-P-13983 (table I) -----										
Cutback asphalt types I, II, III (table I) Fed. SSA-671 -----	30	1.66	30	900	2,400	¹ 100 ² 30	¹ 1 ² 15	¹ 100 ² 30	¹ 2,000 ² 900	¹ 8,000 ² 2,400
Used crankcase oil (table III) -----						50	1	50	1,500	4,000
Stains, table I -----										
Coating compound, bituminous emulsion MIL-P-3840 (table I) -----	45	1.1	45	1,350	3,600	45	1.1	45	1,350	3,600
Asphalt cement (table III) -----	50	.2	50	N/A	4,000	50	.2	50	N/A	4,000
Water, paint, paste MIL-P-18358 (table I) -----										

See footnotes at end of table.

Table 52.1. Coverage Data—Continued

Coating material	Glass				Coated or primed metal				Galvanized Metal			
	Brushing		Spraying		Brushing		Spraying		Brushing		Spraying	
	Square feet per gallon	Man-hours per 100 sq. ft.	Square feet per gallon	Square feet per hour	Square feet per gallon	Man-hours per 100 sq. ft.	Square feet per gallon	Square feet per hour	Square feet per gallon	Man-hours per 100 sq. ft.	Square feet per gallon	Square feet per hour
Paint, water, paste MIL-P-13340 (table I).....	600	1	750	3, 000	600	1	750	3, 000	600	1	750	3, 000
Xylene and tar (R-2); kerosene and asphalt (table II).....												
Paint, temporary, paste MIL-P-13983 (table I).....	500	1	600	3, 000	500	1	600	3, 000				
Cutback asphalt types I, II, III (table I) Fed. SSA-671.....	30	1. 66	30	900	30	1. 66	30	900	30	1. 66	30	900
Used crankcase oil (table III).....												
Stains, table I.....												
Coating compound, bituminous emulsion MIL-P-3840 (table I).....	45	1. 1	45	1, 350	45	1. 1	45	900	45	1. 1	45	1, 350
Asphalt cement (table III).....												
Water, paint, paste MIL-P-18358 (table I).....	500	1	600	3, 000	500	1	600	3, 000				

Table 52.1. Coverage Data—Continued

Coating material	Mineral-coated roofing				Rubber				Wood			
	Brushing		Spraying		Brushing		Spraying		Brushing		Spraying	
	Square feet per gallon	Man-hours per 100 sq. ft.	Square feet per gallon	Square feet per hour	Square feet per gallon	Man-hours per 100 sq. ft.	Square feet per gallon	Square feet per hour	Square feet per gallon	Man-hours per 100 sq. ft.	Square feet per gallon	Square feet per hour
Paint, water, paste MIL-P-13340 (table I)-----	450	1	600	3, 000	450	1	600	3, 000	450	1	600	3, 000
Xylene and tar (R-2); kerosene and asphalt (table II)-----												
Paint, temporary, paste, MIL-P-13983 (table I)-----												
Cutback asphalt types I, II, III (table I) Fed. SSA-671-----	30	1. 66	30	900					30	1. 66	30	900
Used crankcase oil (table III)-----												
Stains, table I-----									200	1	200	3, 000
Coating compound, bituminous emulsion MIL-P-3840 (table I)-----	45	1. 1	45	1, 350					45	1. 1	45	1, 350
Asphalt cement (table III)-----												
Water, paint, paste MIL-P-18358 (table I)-----					400	1	475	2, 850	400	1	475	2, 850

Table 52.1. Coverage Data—Continued

Coating material	Grass			Earth, sand, and stabilized soil			Glass fiber and steel wool		Feather-garnished and mineral-fiber-garnished netting	
	Spraying			Spraying			Spraying		Spraying	
	Square feet per gallon	Sprayer (square feet per hour)	Pressure distributor (square feet)	Square feet per gallon	Sprayer (square feet per hour)	Pressure distributor (square feet)	Square feet per gallon	Sprayer (square feet per hour)	Square feet per gallon	Sprayer (square feet per hour)
Paint, water, paste MIL-P-13340 (table I)							600	3, 000	600	6, 000
Xylene and tar (R-2); keorsene and asphalt (table II)										
Paint, temporary, paste, MIL-P-13983 (table I)										
Cutback asphalt types I, II, III (table I) Fed. SSA-671	100	2, 000	8, 000	100	2, 000	8, 000				
Used crankcase oil (table III)				20	60	1, 600				
Stains, table I										
Coating compound, bituminous emulsion MIL-P-3840 (table I)	100	2, 000	8, 000	100	2, 000	8, 000				
Asphalt cement (table III)										
Water, paint, paste MIL-P-18358 (table I)									350	5, 250

¹ Cutback asphalt types II and III only.² Cutback asphalt type I only.

CHAPTER 6

ROADS AND BRIDGES

Section I. MILITARY ROADS

52. General

FM 5-36 covers route reconnaissance and classification. TM 5-250 deals with reconnaissance, design, construction, maintenance, and repair of roads and airfields. TM 5-252 deals with the use of road and airfield construction equipment. TM 5-253 deals with bituminous construction. TM 5-560 includes material on road construction in Arctic conditions. TM 5-624 deals with the repair of roads and runways. TM 5-260 covers the principles of bridging. TM 5-271 discusses light stream crossing equipment. Numerous TM's of the 5- series describe individually the various types of standard bridging, and of road, bridge, and airfield construction equipment.

53. Design

a. The specifications listed in table 53 will, under most conditions, give a combat road which will meet military requirements; conserve time, labor, equipment, materials, and transportation; and provide at least minimum driving safety. Those specifications related primarily to safety are not to be considered as "must" specifications, but rather specifications to be met whenever possible and without undue sacrifice of other considerations. Although they are not rigidly required, this does not mean that they are not important.

b. Figures 9 and 10 are a cross section and a perspective illustrating road nomenclature.

Table 53. Summary of Military Road Specifications

	Characteristic	Specification
1	WIDTH:	
	Traveled way (single lane).....	Minimum—12 feet.
	Traveled way (two lanes).....	Minimum—22 feet. 23 Fm 5-36
	Shoulders (each side)-----	Minimum—4 feet.
	Clearing-----	Minimum—6 feet on each side of roadway.
2	ALINEMENT (based on 25 to 35 m.p.h.):	
	Grades:	
	Absolute maximum-----	Lowest maximum gradability of vehicles for which road is built.
	Normal maximum-----	10 percent.
	Desirable maximum-----	Tangents and gentle curves, less than 6 percent; sharp curves, less than 4 percent.

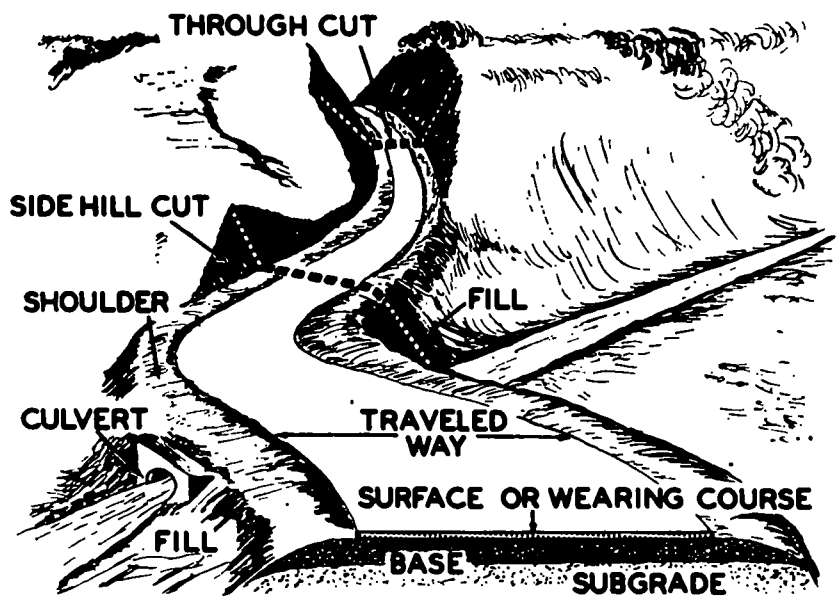


Figure 10. Perspective of road illustrating road nomenclature.

54. Construction

a. Earthwork. Volumes of earth to be moved are computed in order to facilitate the scheduling of equipment and the balancing of cut and fill. This is generally done by using the average end area formula or the average cut or fill table.

(1) The average end area formula is:

$$V = \frac{(A_1 + A_2)L}{54}$$

where,

V = volume, cu. yds.

A_1 and A_2 = end areas, sq. ft.

L = distance between end areas, ft.

(2) Having only the centerline profile plotted and the grade established, earthwork can be estimated from table 54.

b. Drainage.

(1) Ditches.

(a) The size and gradient of ditches and open channels may be determined by Manning's formula:

$$Q = A \frac{1.486}{n} R^{2/3} S^{1/2}$$

where,

Q =discharge, cu. ft./sec.

A =cross-sectional area of flow, sq. ft.

R =hydraulic radius $\left(\frac{\text{area of section}}{\text{wetted perimeter}}\right)$, ft.

S =slope, feet/foot.

n =coefficient of roughness.

1. The desirable grades are between 0.5 percent and 4 percent.
2. The coefficient n varies between 0.025 for ditches in good condition and 0.040 for ditches in poor condition.
- (b) Maximum mean velocities permissible in table 55. The velocity is determined by Q/A .
- (c) When the ditch grade exceeds 4 percent, checkdams are used. Checkdams are spaced according to the formula:

$$S = \frac{100 H}{A - B}$$

where,

S =distance between checkdams, ft

H =height of checkdam, ft

A =grade of ditch, %

B =grade of water level, %

(2) Culverts.

- (a) The size culvert required to bridge a small stream (less than 10 feet) can be determined from

$$A = (B_1 + B_2) H$$

where,

A =cross-sectional area of culvert, sq. ft.

B_1 =width of stream at bottom, ft.

B_2 =width of stream at high water mark, ft.

H =depth of high water mark, ft.

- (b) The size of culvert required to carry surface runoff can be calculated using Manning's formula or Talbot's formula. The values of n for use in Manning's formula are given in table 56.

Talbot's formula is used as an approximate method for hasty calculations and is:

$$A = C\sqrt[4]{D^3}$$

where,

A =cross-sectional area of culvert, sq. ft.

B =drainage area, acres

C =coefficient depending on terrain characteristics

Figure 11 is an alinement chart for solution of Talbot's formula.

Table 54. Volume of Cuts and Fills in Cubic Yards per 100 Feet of Length (for Level Sections)

1	2	3	4	5	6	7	8	9	10	11	12
Average depth of cut or height of fill (feet)	Side slope 1 to 1—width of base of cut or crown of fill (feet) ¹								Add for each additional 2 feet of width	Add where slope is 1½ to 1	Add where slope is 2 to 1
	14	16	18	20	24	28	30	42			
1.....	56	63	70	78	92	107	115	159	7	2	4
2.....	119	133	148	163	192	222	237	326	15	7	15
3.....	189	211	233	256	300	344	367	500	22	16	33
4.....	267	296	326	356	415	474	504	682	30	30	59
5.....	352	389	426	463	537	611	648	870	37	46	93
6.....	444	489	533	578	667	756	800	1,065	45	67	133
7.....	544	596	648	700	803	907	959	1,271	52	91	181
8.....	652	711	770	830	948	1,067	1,126	1,483	59	118	237
9.....	767	833	900	967	1,100	1,233	1,300	1,700	67	150	300
10.....	889	936	1,037	1,111	1,259	1,407	1,481	1,928	74	185	370
11.....	1,019	1,100	1,181	1,263	1,426	1,589	1,670	2,159	82	224	448
12.....	1,156	1,244	1,333	1,422	1,600	1,778	1,867	2,400	89	267	534
13.....	1,300	1,396	1,493	1,589	1,781	1,974	2,070	2,649	96	313	626
14.....	1,452	1,556	1,659	1,763	1,970	2,178	2,281	2,904	104	363	725
15.....	1,611	1,722	1,833	1,944	2,166	2,389	2,500	3,167	111	426	852
16.....	1,778	1,896	2,015	2,133	2,370	2,607	2,726	3,437	119	474	948
17.....	1,952	2,078	2,204	2,330	2,581	2,833	2,959	3,715	126	534	1,068
18.....	2,133	2,267	2,400	2,533	2,800	3,067	3,200	4,000	133	598	1,196
19.....	2,322	2,463	2,604	2,744	3,025	3,307	3,448	4,293	141	667	1,334
20.....	2,519	2,667	2,815	2,963	3,259	3,556	3,704	4,593	148	740	1,480
21.....	2,722	2,878	3,033	3,189	3,500	3,811	3,967	4,900	156	815	1,630
22.....	2,933	3,096	3,259	3,422	3,748	4,074	4,237	5,215	163	894	1,788

¹ Width of roadbed on fills should be for 2 feet greater than in cuts.

Table 55. Maximum Mean Velocities Permissible in Unlined Ditches

Material	Mean velocity (feet per second)
Uniformly graded sand and cohesionless silts.....	0. 7-1. 5
Well-graded sand.....	1. 5-2. 5
Silty sand.....	2. 5-3. 0
Clays.....	3. 0-5. 0
Coarse gravel and cobbles.....	5. 0-8. 0

Table 56. Values of n for Manning's Formula

Boundary surface	Manning n
Well-planed timber.....	0. 009
Finished concrete.....	. 012
Concrete and clay sewer pipe, smooth, with smooth, rounded connections.....	. 013
Other concrete pipe with ordinary alinement and jointing, average brickwork, unplanned timber.....	. 015
Concrete laid in rough forms, poor brickwork, good rubble masonry..	. 017
Corrugated metal pipe, bituminous paved invert.....	. 019
Corrugated metal pipe, plain and bituminous coated.....	. 021
Canals and ditches, good condition.....	. 025
Canals and ditches, poor condition.....	. 040

c. Quarry and Gravel-Pit Equipment. Table 57 gives the output capacity of standard quarry and gravel-pit equipment.

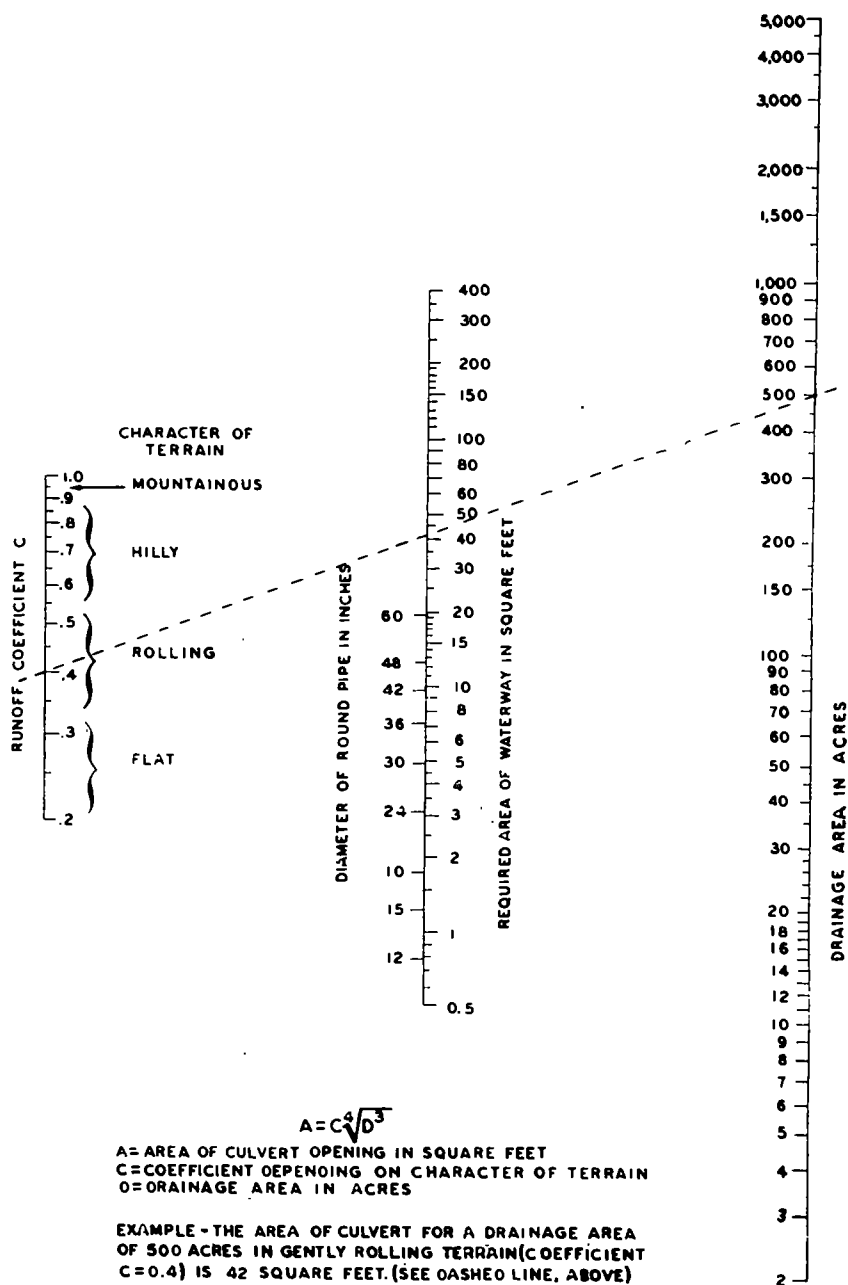


Figure 11. Alinement chart for solution of Talbot's formula.

Table 57. Output Capacity of Quarry and Gravel-Pit Equipment

Equipment	Shipping weight (pounds)	Cubage (cubic feet)	Dimensions			Powered by—	Crusher	Output (tons per hour)			
			Length	Width	Height			Size	Tons	Size	Tons
150 tons per hour, 14-unit unit quarry set: Crushers:											
Primary unit (Pioneer 153 PRA).	85, 000	5, 143	37' 3"	10' 5"	13' 3"	Diesel.....	Jaw 30" by 42" will take rocks 28" by 40".	4" 140-190 6" 250-350	5" 185-265 8" 340-500		
Intermediate unit (Pioneer 54 VAE).	78, 150	5, 518	43' 4"	9' 8"	13' 2"	Diesel.....	Roll 54" by 24".	2" 256 3" 384 1/4" 24 3/4" 72 1 1/4" 118 2" 190 3" 287	1 1/2" 192 2 1/2" 321 4" 512 1/2" 48 1" 95 1 1/2" 143 2 1/2" 238		
Washing unit (Pioneer 300 WAE).	56, 490	6, 170	44' 7"	10' 3"	13' 6"	Diesel.....	Roll 40" by 22".				
Intermediate (Pioneer 42 VAE).	54, 700	3, 866	29' 6"	10' 1"	13' 0"	Diesel.....	Roll 40" by 22".	(1)	(1)	(1)	(1)
Transfer spout.....	795	313									
30" by 40" conveyor.	5, 655	1, 389				Electric motor					
Sand dehydrator.....	14, 300	2, 181				Electric motor.					
Return conveyor swivel stand.	150	25						(2)	(2)		
Transfer spout.....	720	341			10' 9"						
Log washer.....	38, 800	2, 750	24' 7"	9' 9"	14' 6"	Diesel.....					

Conveyors:									
Feeder, 30'' by 50'----	8, 400	1, 390	-----	-----	-----	Electric motor.	(3)	(3)	(3)
Upper half of conveyor.	-----	688	27' 4''	4' 4''	6' 0''	-----	-----	-----	-----
Lower half of conveyor.	-----	464	29' 0''	4' 2''	4' 0''	-----	-----	-----	-----
Cradle-support frame.	-----	38	4' 2''	4' 5''	2' 0''	-----	-----	-----	-----
Axle frame.	-----	140	13' 7''	10' 2''	12''	-----	-----	-----	-----
Ram frame.	-----	43	15' 1''	4' 4''	8''	-----	-----	-----	-----
Wheels and tires.	-----	17	3' 1''	2' 11''	1' 10''	-----	-----	-----	-----
Sand delivery, 30'' by 50'.(4)	-----	-----	-----	-----	-----	-----	-----	-----	-----
Rock delivery, 30'' by 50'.(4)	-----	-----	-----	-----	-----	-----	-----	-----	-----
Return, 30'' by 35'----	6, 940	1, 052	-----	-----	-----	Electric motor.	(5)	(5)	(5)
Upper half of conveyor.	-----	530	22' 1''	4' 4''	5' 8''	-----	-----	-----	-----
Lower half of conveyor.	-----	284	18' 9''	4' 2''	3' 5''	-----	-----	-----	-----
Cradle-support frame.	-----	38	4' 2''	4' 5''	2' 0''	-----	-----	-----	-----
Axle frame.	-----	140	13' 7''	10' 2''	12''	-----	-----	-----	-----
Ram frame.	-----	43	15' 1''	4' 4''	8''	-----	-----	-----	-----
Wheels and tires.	-----	17	3' 1''	2' 11''	1' 10''	-----	-----	-----	-----
Reciprocating plate feeder and 30'' by 21' conveyor.	3, 820	450	-----	-----	-----	Electric motor.	(2)	(2)	-----
	2, 900	526	-----	-----	-----	Electric motor.	(2)	(2)	-----
Pumping unit.	6, 120	772	-----	-----	-----	Gasoline	-----	-----	-----
Piping equipment.	19, 980	1, 500	-----	-----	-----	-----	-----	-----	-----
Power unit and control panel.	13, 320	1, 608	-----	-----	-----	Diesel.	-----	-----	-----

See footnotes at end of table.

Table 57. Output Capacity of Quarry and Gravel-Pit Equipment—Continued

[illegible]

Vibrating screen.....			8' 0''	3' 0''		V-bolts from main plant.					
Delivery conveyor ⁹											
Sand conveyor ⁹											
Roll conveyor ¹⁰											
Crushing and screening plant, 1-unit, 50 tons per hour:											
Crusher (Pioneer Model 33 Triplex):											
Jaw.....						Jaw, 18'' by 30''.					
Triple roll.....			11' 7½''	7' 2''	7' 8¼''	Triple roll, 30'' by 18''.	{ ¼'' ¾'' 1¼'' 2''	17 52 86 138	½'' 1'' 1½''	35 69 103	

¹ Same as washing unit.

² Adequate.

³ Conveyor capacity is adequate to handle output of units it serves. Belt speed is 300 or 400 f.p.m.

⁴ Same as feeder conveyor.

⁵ Conveyor capacity is adequate to handle output of units it serves. Belt speed is 300 f.p.m.

⁶ Plate width, 20½". Hopper size, 5' 6" by 5' 6" opening. Hopper capacity: level 1½ cubic yards; heaped 2 cubic yards.

⁷ Belt 18 inches wide, 18' 0" pulley centers.

⁸ Belt 18 inches wide, 20' 7" pulley centers.

⁹ Belt 18 inches wide, 14' 0" pulley centers.

¹⁰ Belt 18 inches wide, 7' 11" pulley centers.

55. Maintenance

a. Ditches and culverts must be kept open on all roads. Maintenance and repairs required on various types of surface are shown in table 58.

Table 58. Road Maintenance and Repair

Type of surface	Maintenance	Repair
Portland-cement concrete, asphaltic concrete, brick, stone, or wood block.	Clean dust and dirt from joints and cracks and refill with hot asphalt, tar, or a cement grout.	Repair by patching with bituminous premix, or with original material.
Bituminous surfaces.	Occasional renewal of wearing surface by adding seal coat with mineral-aggregate cover.	Soft spots and breaks: Remove surface; correct drainage, base and/or subgrade; trim and square area to be patched; replace surface with bituminous premix. Ruts, waves, and shoves: Usually caused by excess bituminous material, improper curing or defective drainage. The latter may require complete removal of pavement. If pavement is roadmix type, scarify and disk material until broken up, blade from side to side of strip. If necessary add aggregate, reshape and roll. Apply seal coat if needed. In surface treatments; usually indicates bond between bituminous treatment and base course broken. Remove wearing course, recondition and reprime base, apply new surface treatment. Use surface material similar to original. Worn and raveled surface: In mixed material, remove surface full depth over defective area, cut square or rectangular opening with vertical edges. Clean base and apply tack coat, place mix and tamp, roll and check surface. In penetration-macadam or similar surface, repair by surface treating affected area with material similar to original pavement.

Table 58. Road Maintenance and Repair—Continued

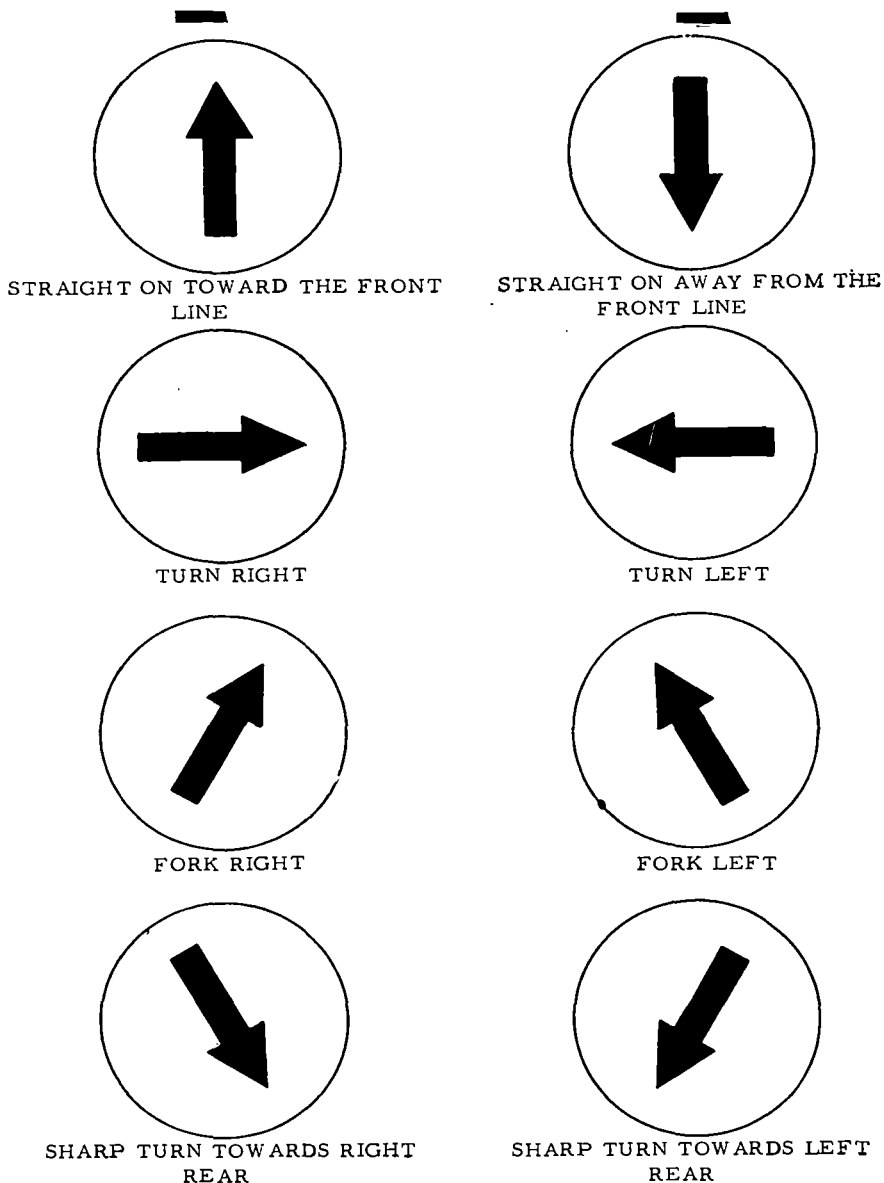
Type of surface	Maintenance	Repair
Untreated surfaces of gravel, crushed rock, sand-clay, etc. (includes surfaces treated with dust palliatives).	Reshape periodically, preferably while damp, using blade grader or road drag. If surface develops corrugations it should be scarified and reshaped. Periodically add additional surfacing to replace that worn and washed away. Dust palliatives may be applied periodically as needed during dry season.	Soft spots: Remove surface; correct base, subgrade or drainage difficulty; trim and square area; replace and compact surfacing. Repair of soft spot may sometimes be made by adding new layer of surfacing, keeping it maintained while it is being compacted by traffic.
Earth-----	Reshape periodically, preferably while damp, using blade grader or road drag. Dust palliatives may be applied periodically as needed during dry season.	Soft spots: Correct drainage and cover or mix with granular material to stabilize.
Corduroy-----	Maintain cover of brush and earth. Respike logs.	Reconstruct sections as required.
Plank-----	Replace broken timbers. Keep well spiked.	Reconstruct sections as required.

b. Engineer units instruct and assist the using forces in the use of truck-drawn steel-edged timber drags for maintenance of interior roads in depots, bivouac areas, hospitals, and similar areas.

56. Road Signs

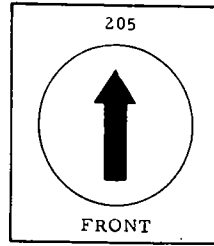
a. The designs and specifications for materials for road signs are responsibilities of the Chief of Engineers. Making road signs is an engineer responsibility. Posting them is an engineer responsibility coordinated with the appropriate provost marshal and the highway traffic regulation officer of the Transportation Corps regarding location and the number used. Operational responsibility for road signing is a command function.

b. Figures 12 through 19 show typical road signs of various categories. For further details see AR 420-72; the Manual on Uniform Traffic Control Devices dated 1948 (Public Roads Administration) as modified by the Revision dated 1954 (Bureau of Public Roads); and FM 5-36.

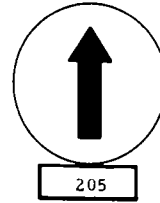


ALL DISKS HAVE MINIMUM DIAMETERS OF 1 FOOT.

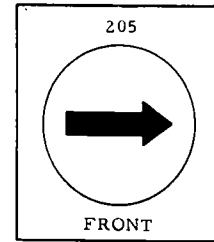
Figure 12. Directional disk marking.



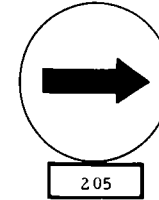
MAIN SUPPLY ROUTE
205 FRONT GOING
TRAFFIC STRAIGHT ON



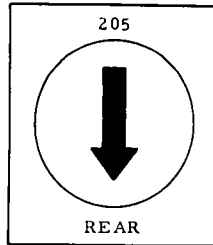
ALTERNATIVE FOR
SUPPLY ROUTE 205
FRONT GOING TRAF-
FIC STRAIGHT ON



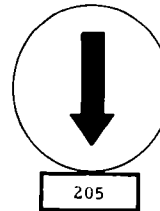
MAIN SUPPLY ROUTE
205 FRONT GOING
TRAFFIC TURN RIGHT



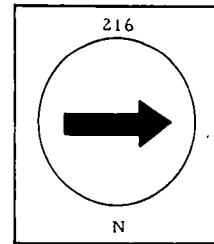
ALTERNATIVE FOR
MAIN SUPPLY ROUTE
205 TURN RIGHT



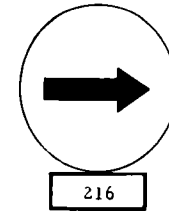
MAIN SUPPLY ROUTE
205 REAR GOING TRAF-
FIC STRAIGHT ON



ALTERNATIVE FOR
MAIN SUPPLY ROUTE
205 REAR GOING TRAF-
FIC STRAIGHT ON



LATERAL ROUTE 216
NORTH GOING TRAFFIC
TURN RIGHT



ALTERNATIVE FOR
LATERAL ROUTE 216
TURN RIGHT

ALL CIRCLES OR CIRCULAR DISKS HAVE MIN. DIA. OF 1 FOOT.

Figure 13. Route signs.



(24" X 9")



(VARIABLE SIZE)



(VERTICAL- 24" HORIZONTAL-
VARIABLE. MINIMUM-24")



(40" X 24")



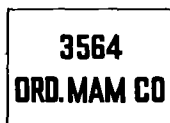
(24" X 24")



(40" X 24")



(40" X 24")



(30" X 24")



(40" X 24")

Figure 14. Guide signs.



(12" X 18")



(24" X 24")



(18" X 24")



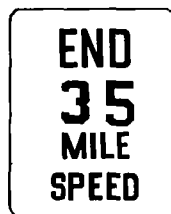
(36" X 12")



(12" X 18")



(14" X 9")

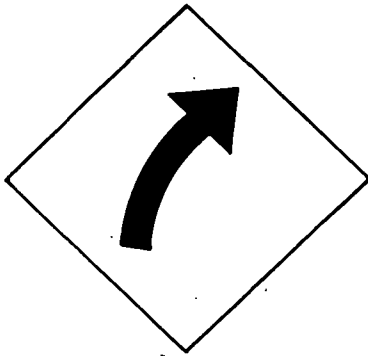


(18" X 24")

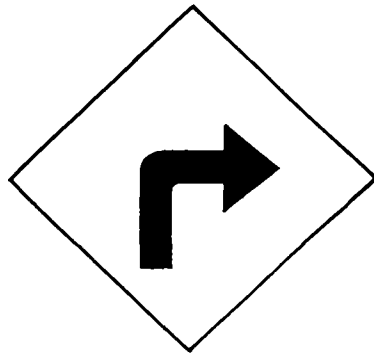


(18" X 24")

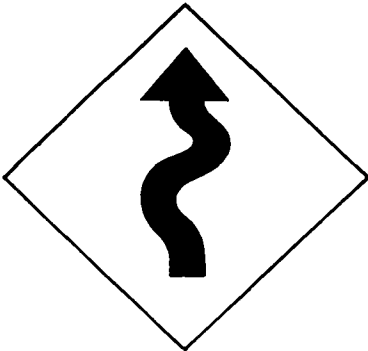
Figure 15. Regulatory signs.



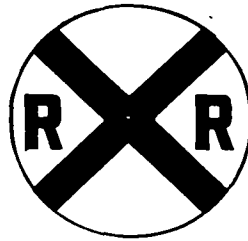
CURVE TO RIGHT
24" X 24"



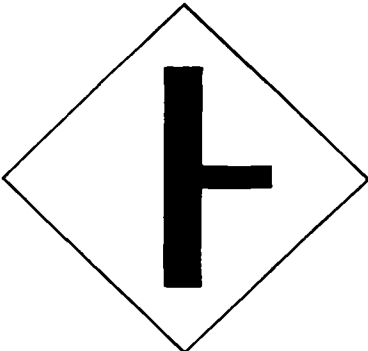
SHARP CURVE TO RIGHT
24" X 24"



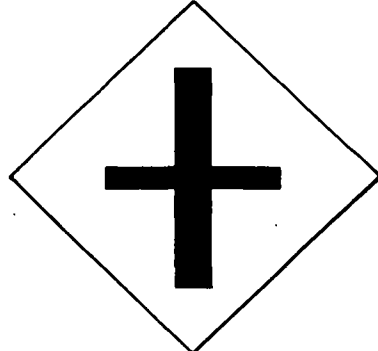
WINDING CURVES
24" X 24"



RAILROAD CROSSING
DIM. (30" DIA.)



T-JUNCTION
24" X 24"



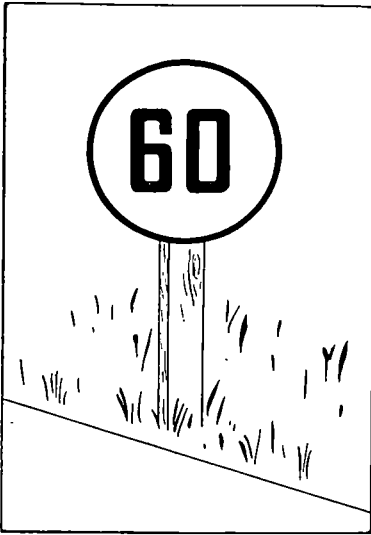
**PRIMARY ROAD CROSSING
SECONDARY ROAD**
24" X 24"

Figure 16. Warning signs.

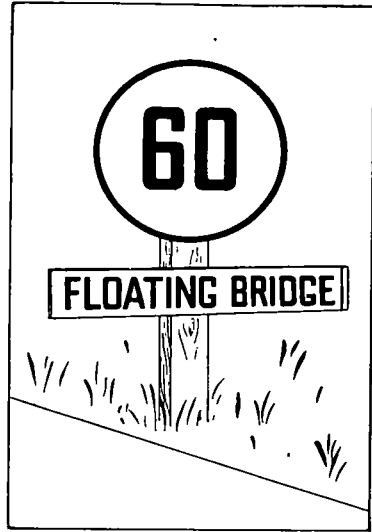


ALL SIGNS ABOVE (24" X 24")

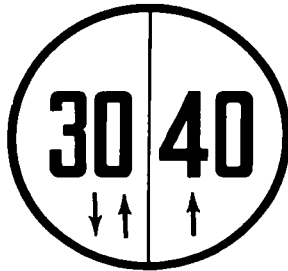
Figure 16.—Continued



①



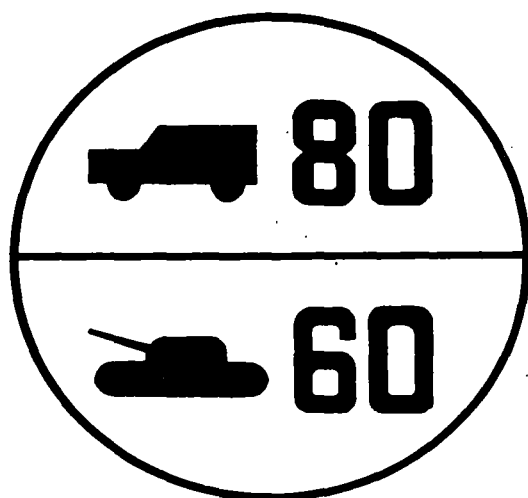
②



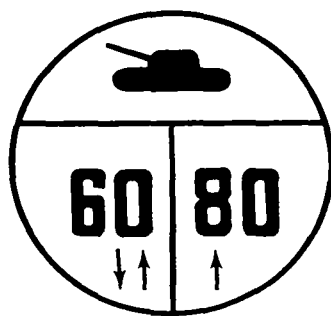
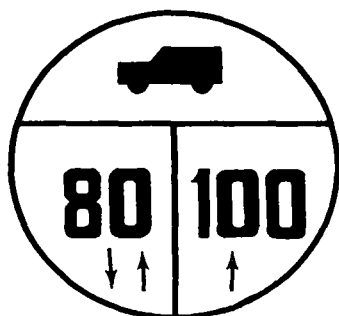
③

(MINIMUM DIA. OF DISKS, 12")

Figure 17. Bridge class and information signs.



①



②

(MINIMUM DIA. OF DISKS 12")

Figure 18. Dual-class bridge signs.

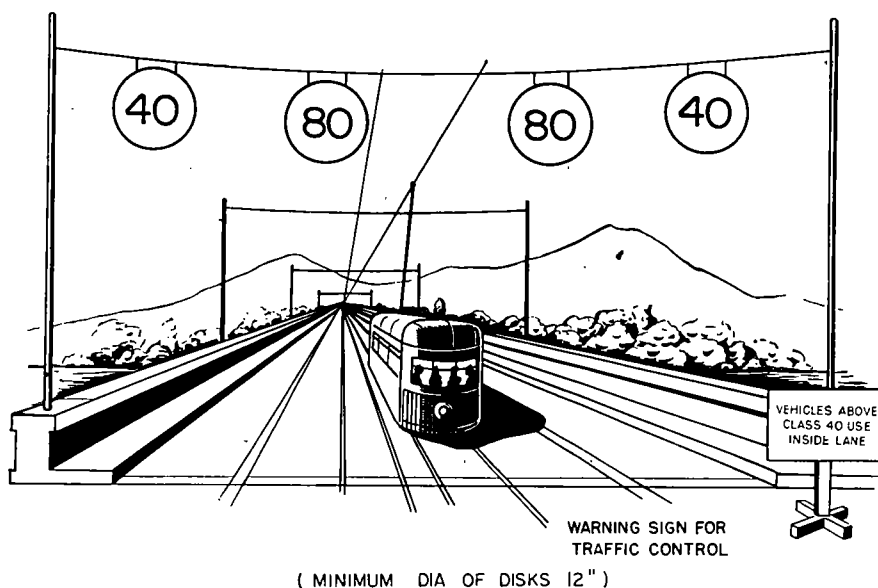


Figure 19: Multilane bridge signs.

Section II. STREAM CROSSING EQUIPMENT

57. General

The siting, design, and erection of standard, prefabricated, floating, and fixed highway bridges are covered in the TM 5-270-series. Construction and logistical data pertinent to these bridges are tabulated in FM 101-10. Prefabricated semipermanent steel highway bridges for 30-, 60-, and 90-foot spans are covered in TM 5-285; typical semipermanent highway and railroad trestle bridges in TM 5-286; and prefabricated steel railroad bridges in the TM 5-370-series. TM 5-260 deals with the design principles underlying the construction, maintenance, and use of all types of military bridges.

58. Panel Bridge, Bailey Type, M2

For detailed information on the Bailey type M2 panel bridge, see TM 5-277.

59. Semipermanent Steel Highway Bridges, 30-, 60-, and 90-foot Spans

Data on semipermanent steel highway bridges, 30-, 60-, and 90-foot spans are given in table 59.

Table 59. *Semipermanent Steel Highway Bridges, 30-, 60-, and 90-Foot Spans*

Item	Nominal length		
	30 ft.	60 ft.	90 ft.
Type.....	Deck I-beam	Deck I-beam	Through truss
Class.....	50	50	50
Caution class ¹	75	75	70
Weight of one beam or truss, pounds.....	2, 600	10, 000	15, 000
Weight, structural steel and connections, pounds.....	12, 917	45, 788	61, 654
Measured tons, structural steel and connections.....	7. 55	20. 31	48. 56
Quantity of lumber, board feet.....	3, 868	7, 544	10, 608
Measured tons, lumber.....	8. 05	15. 70	22. 10
Man-hours to erect, average.....	453	1, 042	1, 929
Required abutment capacity, tons.....	70. 5	87. 5	88. 5

¹ 1 vehicle on bridge at a time, vehicle on center line of bridge, no braking or gear shifting.

60. Prefabricated Railroad Bridges

There are three bridges in this category: The I-beam railroad bridge (TM 5-371), the unit construction railroad bridge (TM 5-372), and the through-truss railroad bridge (TM 5-373). The relations between type, loading, span length, and maximum speed for the foregoing are given in tables 60, 61, and 62. New equipment is under study which, if adopted, may take the place of the first two types and the semipermanent steel highway bridges described in TM 5-285 as well.

61. Floating Bridges

Data on floating bridges is given in tables 63 and 63.1.

62. Rafts

Data on rafts is given in table 64.

63. Boats

a. General. Below are summarized the principal characteristics of standard Army boats other than ponton boats. For further details see FM 5-271.

b. Assault Boat, Plastic, 16-Foot. The assault boat, plastic, 16-foot, replaced the assault boat, M2. It has a flat bottom, tapered bow, and square stern. It weighs 291 pounds and has a capacity of 3,375 pounds in currents up to 5 f.p.s. and 2,700 pounds in currents up to 8 f.p.s.

Table 60. I-Beam Railroad Bridge

Beam size	Number of beams in bridge	Span length (feet)	Maximum speed, mph, at Cooper's loading of:		
			E-45	E-42½	E-40
18'' WF 55#-----	4	15	40	40	40
		16	40	40	40
		17	25	40	40
		18	25	25	40
	6	19	40	40	40
		20	40	40	40
		21	40	40	40
24'' WF 87#-----	4	22	40	40	40
		23	40	40	40
		24	40	40	40
		25	40	40	40
		26	40	40	40
		27	25	40	40
		28	25	25	40
		29	25	25	40
	6	30	40	40	40
		31	40	40	40
		32	40	40	40
		33	40	40	40
		34	40	40	40
		35	40	40	40

Table 61. Unit Construction Railroad Bridge

Type of bridge	Number of trusses	Span length feet	Maximum speed, mph, at Cooper's loadings of:		
			E-45	E-42½	E-40
Through truss-----	Two-----	55	40	40	40
		60	40	40	40
		65	40	40	40
		70	40	40	40
		75	10	25	40
		80	(¹)	10	25
		85	(¹)	(¹)	10
	Four-----	75	40	40	40
		80	40	40	40
		85	40	40	40
Deck-----	Two-----	55	40	40	40
		60	40	40	40
		65	40	40	40
		70	40	40	40
		75	10	25	40
	Three-----	75	40	40	40
		80	40	40	40
		85	40	40	40

¹ Not permitted.

Table 62. Through-Truss Railroad Bridge

Cooper's loadings	Maximum speeds in miles per hour for span lengths of:						
	92'-3"	102'-6"	112'-9"	123'-0"	133'-3"	143'-6"	153'-9"
Two standard locomotives and train:							
E-45-----	40	40	40	40	10	10	(¹)
E-42½-----	40	40	40	40	20	10	10
E-40-----	40	40	40	40	40	20	20
One standard locomotive and train:							
E-45-----	40	40	40	40	40	20	10
E-42½-----	40	40	40	40	40	40	20
E-40-----	40	40	40	40	40	40	40

¹ Dead slow.

c. *Bridge Erection Boat, 19-Foot.* The bridge erection boat, 19-foot is designed to assist in the assembly of tactical floating bridges and the propulsion of light tactical rafts. It is also used for general utility work during the assembly of rafts or bridges; and it can be used for limited ferrying of personnel or equipment, although this is not economical. It is made of aluminum, with a rounded bow and square stern. It is 19 feet 2½ inches long and when serviced and with accessories weighs 3,800 lbs. Maximum allowable load is 3,000 lbs. It is powered by a 6-cylinder marine-type engine driving a single propeller. There is a 2-man crew.

d. *Bridge Erection Boat, 27-Foot.* The bridge erection boat, 27-foot, has the same general functions as the 19-foot type, but is designed to propel the heaviest types of raft assembled for floating bridge sets. It is made of aluminum, in two sections, with a blunt bow and stern. It is 27 feet ½ inch by 11 feet when assembled and with a pushing knee at the bow, and has a service weight of 6,800 lbs. Maximum allowable load is 3,000 lbs. It is powered by two 6-cylinder marine-type engines driving twin propellers. There is a 2-man crew.

e. *Five-Man Canvas Pneumatic Reconnaissance Boat.* The 5-man canvas pneumatic reconnaissance boat is used primarily for reconnaissance work and combat patrols. It is formed of inflatable cotton-duck tubing 16 inches in diameter, with a double cotton-duck bottom. It is 12 feet by 5 feet 8 inches when inflated, and weighs 120 lbs. with accessories. It has a square stern and raked triangular bow. Maximum cargo capacity is 2,000 lbs. The boat is propelled by paddles.

f. *Boat, Reconnaissance, Pneumatic, Neoprene Coated Cloth. 3-Man Capacity.* The boat is used for transporting 3 men on general reconnaissance missions. The boat is 9' 0" long and 4' 0" wide. The weight of the boat is 31 pounds including carrying case, pump, repair kit, and 3 paddles. The boat is propelled by the use of paddles only.

g. *Boat, Landing, Inflatable: Assault Craft, Nylon Cloth. 15-Man.* The boat is used to transport men and equipment across streams or other water obstacles during assault operations. The boat is propelled by either paddles or outboard motor. The length of the boat is 17' 0" and the width is 6' 3". The weight of the boat including paddles, repair kit, carrying case, and pumps is approximately 260 pounds. The boat loaded with 3,300 pounds can be propelled with paddles in 5-fps current and with a 25-hp outboard in 8 fps current. It also can navigate in very turbulent water having velocities up to 12 fps when propelled by the 25-hp motor.

Table 63. *Classes of Floating Bridges*

Type of bridge		Transportation required ¹	Assembly party ²	Maintenance crew	Class ³															Traffic capacity and vehicular distance for safe crossings in daylight (except as otherwise noted) ⁷
					Normal crossing ⁴ (posted capacity)					Caution crossing ⁴					Risk crossing ⁴					
					Stream velocities in feet per second															
3	5	7	9	11	3	5	7	9	11	3	5	7	9	11						
Aluminum footbridge.....		2-2½t 6 by 6 cargo trucks with 2 pole tirs or 3 dump trucks.			S fe.....													Day: 75 men per minute. Night: 40 men per minute at 2-pace distance.		
M2 assault boat bridge	Normal construction.	1-2½t truck and 1 pole tir per 35 ft. of bridge.	1 plat.....	1 sqd..	8	6	5			8	6	5			9	7	6		200 vehicles per hour; 90 ft. distance between vehicles.	
	Reinforced construction.	1-2½t truck and 1 pole tir per 24 ft. of bridge.	1 plat.....	1 sqd..	13	9	7			13	11	8			14	12	9			
Widened steel treadway bridge.		1-5t bridging truck per 24 ft. of bridge.	1 tdwy bridge co plus 1 combat co.	1 sqd..	50	50	40	30	15	50	50	45	35	20	55	55	50	45	30	

M4 bridge.....	1-2½t lwb bolster truck per 15 ft. of bridge (normal construction).	1 ponton br co plus 1 or 2 combat cos.	1 sqd..	60	60	50	35	20	65	65	55	45	30	70	70	60	50	40
				° 100	° 100	° 100	° 70	° 40	° 105	° 105	° 105	° 85	° 55	° 110	° 110	° 100	° 100	° 70
Class 60 bridge.....	1-5t bridging truck per bay.			65	65	° 55	45	25	70	70	60	50	35	80	80	70	60	50
M4T6 bridge.....	2-2½t 6 by 6 cargo trucks, or 1-5t bridging truck per bay.			° 55	° 55	50	40	30	60	60	55	45	35	70	70	65	55	45

¹ Transportation for bridge equipment only. Additional needed for any construction equipment required, and for troops.

² Average for trained troops and continuous daylight assembly. Allowances are required for specific situations.

³ Based on abutments at levels within 12 inches of floating bridge deck level.

⁴ Vehicle anywhere on width of bridge deck. Speeds: 15 mph recommended; up to 25 mph permitted.

⁵ Center of vehicle within 12 inches of bridge centerline. Maximum speed 8 mph. Vehicle spacing 150 ft. No sudden stopping or acceleration.

⁶ Center of vehicle within 9 inches of centerline and with guide. Maximum speed

3 mph. One vehicle on bridge. No stopping, braking or gear shifting.

⁷ Traffic capacities are for all traffic moving forward or rearward.

⁸ Use 2-space distance for 3 fps only; 1-bay distance for 4 and 5 fps; 2-bay distance for 6 and 7 fps.

⁹ Normal assembly Reinforced assembly

¹⁰ Tanks weighing up to 60 tons, and with an out-to-out track width of 143 inches or more, make normal crossings in stream velocities up to 7 fps.

¹¹ Any class 50 vehicle with out-to-out track or tire width equal to or exceeding 144 inches can make a normal crossing in currents up to 5 fps.

Table 63.1. Dual Classification Floating Bridge Capacities

Bridge	Type of constr.	Safe Normal					Caution					Risk				
		3	5	7	9	11	3	5	7	9	11	3	5	7	9	11
M2 Assault boat bridge*-----	Normal-----	8	6	5	-----	-----	8	6	5	-----	-----	9	7	6	-----	-----
	Reinf.-----	13	0	7	-----	-----	13	11	9	-----	-----	14	12	0	-----	-----
Widened steel treadway bridge (w/plywood tdwy) (1)-----	-----	(45) 50	(45) 50	(35) 40	(25) 30	(12) 15	(48) 51	(47) 50	(43) 46	(31) 34	(16) 10	(55) 58	(54) 57	(52) 55	(41) 44	(25) 28
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Class 60 bridge-----	Normal-----	(60) 65	(55) 65	(45) 55	(35) 45	(22) 25	(65) 70	(62) 67	(56) 61	(45) 49	(34) 37	(75) 79	(72) 77	(67) 72	(57) 62	(46) 50
	Reinf. (2)-----	(85) 85	(85) 85	(85) 85	(65) 70	(30) 35	(90) 90	(90) 90	(90) 90	(75) 79	(47) 51	(100) 100	(100) 100	(100) 100	(90) 93	(70) 74
M4 bridge-----	Normal (3)-----	(60) 60	(60) 60	(45) 50	(30) 35	(18) 20	(68) 68	(65) 65	(58) 59	(44) 46	(20) 31	(72) 72	(68) 68	(61) 52	(53) 54	(37) 39
	Reinf. (4)-----	(100) 100	(100) 100	(100) 1-0	(70) 70	(35) 40	(105) 105	(105) 105	(105) 105	(85) 85	(55) 55	(110) 110	(110) 110	(110) 110	(100) 100	(70) 70
M4T6 bridge-----	-----	(50)	(45)	(40)	(30)	(25)	(60)	(58)	(54)	(45)	(35)	(68)	(66)	(62)	(54)	(43)

Notes. 1. *Wheeled and track vehicles have the same rating.

2. Upper figure represents wheel load class. Example (43)

Lower figure represents tracked load class. 45

3. (1) Vehicles required to use plywood treadway lane limited to Class 16 Safe, Class 18 Caution, Class 24 Risk.

4. (2) Ratings given are for floating portion of bridge. End span ratings with present superstructure limited to Class 70 Safe, Class 80 Caution, and

Class 90 Risk. Development of satisfactory landing bay not yet complete.

5. (3) Ratings given are for an 18-balk roadway and a 22-balk deck.

6. (4) Ratings given are for a 20-balk roadway and a 24-balk deck in the floating portion, and a 20-balk roadway and a 22-balk deck with a superimposed deck in the end span.

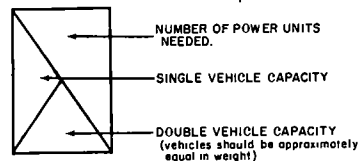
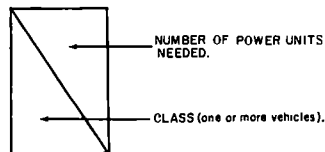
Table 64. Classes of Rafts

Type of raft	Number of pontoons or floats	Length		Assembly party	Operating crew	Class of raft and number of power units needed ^b								Type of power unit required	Transportation required (for raft equipment only. Additional needed for construction equipment and troops)	
		Overall including ramps	Available for loading ^a			Normal crossing*				Risk crossing*					No. units	Unit
						Stream velocity fps				Stream velocity fps						
						5	7	9	11	5	7	9	11			
Infantry support.	3.....	38'-0"	24'-0"	1 plat...	1 sqd...	1 8	2 4			1 9	2 5	(0) 2	Outboard motors—25 horsepower.	1	2½-ton cargo truck w/pole trailer.	
	5.....	50'-0"	35'-9"			2 10	3 5			2 13	3 8	(0) 3		2	2½-ton cargo truck w/pole trailer.	
	7.....	62'-0"	47'-9"			2 13	4 8 13			2 15	4 10 16	(0) 5 8				
M4 of.....	4.....			1 plat...	1 sqd...	1 (50) 55	1 (50) 55	2 (50) 55	3 (40) 45	1 (55) 60	1 (55) 60	2 (55) 60	3 (45) 50	27-foot bridge erection boats. ^d	5	
	6.....	87'-0-¾	51'-8"			1 (70) 75	1 (70) 75	2 (65) 70	3 (50) 55	1 (75) 80	1 (75) 80	2 (75) 80	3 (55) 60		6	2½-ton bolster truck with trailer.
	7.....					1 (85) 90	1 (85) 90	2 (80) 85	4 (55) 60	1 (90) 95	1 (90) 95	2 (90) 95	4 (65) 70		7	
Class 60.....	4, Normal.....	92'-5"	51'-0"			1 (40) 45	2 (40) 45	3 (35) 40	4 (25) 30	1 (50) 55	2 (50) 55	3 (45) 50	4 (35) 40		5	5-ton bridge truck.

*Number in parentheses represents wheeled vehicle class. Number without parentheses represents tracked vehicle class.
See notes at end of table.

Table 64. Classes of Rafts—Continued

Type of raft	Number of pontoons or floats	Length		Assembly party	Operating crew	Class of raft and number of power units needed ^b								Type of power unit required	Transportation required (for raft equipment only. Additional needed for construction equipment and troops)	
		Overall including ramps	Available for loading ^a			Normal crossing*				Risk crossing*					No. units	Unit
						Stream velocity fps				Stream velocity fps						
						5	7	9	11	5	7	9	11			
Class 60	4, Reinforced..	83'-1"	40'-0"	1 plat..	1 sqd..	1 (45) 55	2 (40) 45	3 (35) 40	4 (25) 30	1 (55) 60	2 (50) 55	3 (45) 50	4 (35) 40	27-foot bridge erection boats. ^d	5	5-ton bridge truck.
	5, Normal.....	107'-5"	66'-0"			1 (50) 55	2 (50) 55	4 (40) 45	5 (30) 35	1 (60) 65	2 (60) 65	4 (50) 55	5 (40) 45		6	5-ton bridge trucks.
	5, Reinforced..	92'-5"	54'-6"			1 (55) 60	2 (55) 60	4 (45) 50	5 (35) 40	1 (60) 70	2 (60) 65	4 (55) 60	5 (45) 50			
	5, Reinforced..	83'-1"	43'-9"			1 (60) 65	2 (60) 65	4 (50) 55	5 (45) 50	1 (70) 75	2 (70) 75	4 (60) 65	5 (55) 60			
	6, Reinforced..	92'-5"	57'-0"			1 (65) 75	2 (65) 75	4 (60) 65	5 (50) 55	1 (80) 90	2 (80) 90	4 (70) 80	6 (60) 70			
	6, Reinforced..	98'-9"	50'-10"			1 (60) 70	2 (60) 70	4 (55) 60	5 (45) 50	1 (75) 85	2 (75) 85	4 (65) 75	6 (55) 65			
M4T6	4	87'-1"	51'-8"	1 plat..	1 sqd..	1 (50) 55	1 (45) 50	3 (35) 40	4 (30) 35	1 (60) 65	2 (55) 60	3 (45) 50	4 (35) 40	27-foot bridge erection boats. ^d	5	5-ton bridge trucks.
	5, Reinforced..	88'-9"	50'-1"			1 (60) 65	2 (60) 65	3 (55) 60	5 (45) 50	1 (70) 75	2 (70) 75	3 (65) 70	5 (55) 60		5 1	5-ton bridge truck. 2½-ton cargo truck.



Operating characteristics of rafts	Stream width (feet)		
	250	500	1,000
Number of round trips per hr in currents of 5 fps in daylight (reduce 50% for night or adverse conditions).....	10	6	4
Number of rafts which can be used efficiently at one site.....	1	2	3

*Number in parentheses represents wheeled vehicle class. Number without parentheses represents tracked vehicle class.

- * Measured from outside edge to outside edge of end pontoons or float saddle beams.
- ^b Capacities are based on loading rafts with center of gravity of loads 6" downstream from top of raft and on properly inflated floats.
- ^c One 19-foot bridge erection boat per raft, in current of 9 fps.
- ^d One 19-foot bridge erection boat may be used in currents not over 5 fps. In currents of 5 fps and over, normally two 19-foot bridge erection boats may be substituted for one 27-foot boat.

- * Extreme caution is required in loading and unloading vehicles weighing more than 70 tons.

- ^f Roadway width consists of 18 balk between curbs with 22 balk overall.
- ^g Roadway width consists of 17 balk between curbs with 20 balk overall.

64. Nonstandard Fixed Bridges

a. Basic Structural Design. Design loads, allowable working stresses, properties of sections, and other data on structural design are given in chapter 9 and in standard handbooks in unit libraries.

b. Bridge Design and Construction. The design, construction, and capacity estimation of fixed timber bridges are covered in TM 5-260. Typical designs for nonstandard, semipermanent fixed highway and railroad bridges, with man-hour and material requirements, are given in TM 5-286. The data therein and in table 65 are based generally on experience personnel and good working conditions and on the use of power tools wherever possible.

Table 65. Bridge Construction Man-Hour Data

Operation	Unit	Man-hours per unit	Number of men in crew
Steel:			
Handling ¹	Ton.....	7. 000	7
Bolting.....	Bolt.....	. 060	2
Chipping.....	Lin ft.....	. 083	1
Cutting (oxyacetylene).....	Lin ft.....	. 067	2
Drilling.....	Lin ft.....	3. 200	2
Driving steel piles.....	Lin ft.....	. 133	8
Span erection.....	Ton.....	2. 500	9
Tower erection.....	Ton.....	3. 500	9
Laying out.....	Hole.....	. 040	2
Pattern making.....	.....	.....	2
Reaming (10% of all holes).....	Hole.....	. 067	2
Riveting fabrication.....	Rivet.....	. 100	4
Riveting erection.....	Rivet.....	. 150	4
Welding.....	Lb.....	. 700	2
Timber:			
Handling ²	Bd ft.....	. 010	7
Boring.....	Lin ft.....	. 100	2
Driving driftbolts.....	Bolt.....	. 017	1
Bolting.....	Bolt.....	. 133	2
Driving nails.....	Nail.....	. 003	1
Driving spikes.....	Spike.....	. 008	1
Driving piles.....	Lin ft.....	. 200	8
Handling:			
Span erection.....	Bd ft.....	. 004	9
Tower erection.....	Bd ft.....	. 006	9
Laying out.....	Bd ft.....	. 004	2
Sawing (except piles).....	Sq ft.....	. 033	2
Sawing piles.....	Pile.....	. 167	2
Excavation, hand.....	Cu yd.....	1. 000	7
Cement handling.....	Bbl.....	. 133	9
Piles handling.....	Pile.....	1. 000	7
Sand and gravel handling.....	Cu yd.....	. 500	5
Concrete mixing and placing.....	Cu yd.....	2. 000	24
Scaffolds placement and removal.....	Cu yd.....	.....	4

¹ From arrival through fabrication.

² From arrival through fabrication, excluding span and tower erection.

65. Highway Bridge Stringers

a. For two-lane bridges with an 18- to 30-foot roadway and a 6-inch timber floor, in which the stringer depth is not less than $\frac{1}{8}$ of the span, the total section modulus required for timber stringers for various classes and spans is shown in table 66. For a single-lane bridge less than 18 feet wide, use 0.5 of the section modulus tabulated. For round timber stringers, use 0.6 of diameter as width, and diameter as depth.

b. For stringer depths from 6 to 24 inches, the section modulus per inch width of rectangular timber stringers is tabulated below. (For spans less than 13 times the stringer depth, examine for horizontal shear using the data in paragraph 163c.)

Depth.....	6	8	10	12	14	16	18	20	22	24
Section modulus.....	6	11	16	24	33	43	54	67	81	96

c. Under the same conditions as in a above as to widths and number of lanes, and where the stringer depth is not less than $\frac{1}{10}$ of the span, the total section modulus required in steel stringers is shown in table 67.

d. Section moduli for various steel beams are given in paragraphs 151 to 160.

e. Examples:

- (1) A bridge with a 22-foot roadway has a timber floor carried by six 6- by 16-inch stringers over a 13-foot span. Determine the class. Section modulus from b above is 43 by $36=1,548$. By interpolation in the table in a above, the class is 23.
- (2) Determine the number of 24 WF 76 stringers for a one-lane class 40 bridge with a 6-inch timber floor and a span of 60 feet. From c above, a total section modulus of 1,935 is required for a two-lane bridge; 0.5×1935 or 968 is the total section modulus required for one lane. From paragraph 139, a 24 WF 76 has a section modulus of 175.4; $968/175.4=5.5$; therefore, use 6 stringers.

Section III. CABLEWAYS AND TRAMWAYS

66. Characteristics

Logistical data and other characteristics of cableways and tramways are shown in table 68. For further details see TM 5-270.

67. Details

Details of the cableways and tramways listed in table 61 are given in figures 20 through 23.

Table 66. Section Modulus Required for Two-Lane Bridges, 18- to 30-Foot Roadway with 6-Inch Timber Floor (Timber Stringers)

[Various span lengths in feet]

13 feet		15 feet		17 feet		19 feet		21 feet		23 feet		25 feet	
Class W/T	Section modulus	Class W/T	Section modulus	Class W/T	Section modulus	Class W/T	Section modulus	Class W/T	Section modulus	Class W/T	Section modulus	Class W/T	Section modulus
8	600	8	830	8	985	8	1135	8	1320	8	1490	8	1655
12	870	12	1070	12	1270	12	1480	12	1700	12	1970	12	2232
16	1120	16	1375	16	1645	16	1934	16	2235	16	2545	16	2830
20	1375	20	1695	20	2050	20	2395	20	2775	20	3125	20	3485
24	1615	24	2030	24	2450	24	2855	24	3245	24	3680	24	4130
35/ 30	1750	35/ 30	2270	40/ 30	2695	40/ 30	3285	40/ 30	3750	40/ 30	4305	40/ 30	4735
50/ 40	2200	55/ 40	2790	55/ 40	3445	60/ 40	4130	60/ 40	4795	60/ 40	5430	60/ 40	6145
60/ 50	2585	65/ 50	3355	70/ 50	4160	70/ 50	4905	70/ 50	5735	75/ 50	6565	75/ 50	7395
70/ 60	2925	75/ 60	3695	80/ 60	4720	80/ 60	5690	85/ 60	6690	85/ 60	7740	85/ 60	8825
75/ 70	3180	80/ 70	4210	90/ 70	5240	100/ 70	6360	100/ 70	7450	100/ 70	8600	105/ 70	9865

Note 1. W = wheeled vehicles; T = tracked vehicles.

2. Dual classification for classes of 30 and above.

3. Section modulus in in³.

Table 67. Section Modulus Required for Two-Lane Bridges, 18- to 30-foot Roadway with 6-Inch Timber Floor (Steel Stringers)

[Various span lengths in feet]

15 feet		20 feet		25 feet		30 feet		40 feet		50 feet		60 feet		80 feet		100 feet	
Class W/T	Section modulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus	Class W/T	Section mod- ulus
8	85	8	120	8	165	8	210	8	310	8	430	8	550	8	895	8	1300
12	120	12	160	12	220	12	275	12	410	12	585	12	775	12	1195	12	1690
16	140	16	210	12	280	16	360	12	535	16	705	16	920	16	1415	16	2000
20	170	20	255	20	345	20	440	20	640	20	880	20	1145	20	1755	20	2465
24	205	24	305	24	410	24	515	24	745	24	1020	24	1330	24	2025	24	2830
35/ 30	235	40/ 30	350	40/ 30	480	40/ 30	615	35/ 30	885	35/ 30	1190	30/ 30	1500	30/ 30	2305	30/ 30	3275
55/ 40	285	60/ 40	450	60/ 40	615	60/ 40	780	50/ 40	1150	45/ 40	1525	40/ 40	1935	40/ 40	2880	40/ 40	4055
65/ 50	340	70/ 50	535	75/ 50	745	70/ 50	940	65/ 50	1395	60/ 50	1855	55/ 50	2350	50/ 50	3485	50/ 50	4850
75/ 60	405	85/ 60	620	85/ 60	865	85/ 60	1115	80/ 60	1625	70/ 60	2160	75/ 60	2720	60/ 60	4020	60/ 60	5585
80/ 70	425	100/ 70	700	105/ 70	975	100/ 70	1255	95/ 70	1870	85/ 70	2500	80/ 70	3195	70/ 70	4630	70/ 70	6410

Note 1. W=wheel vehicles; T=tracked vehicles.

2. Dual classification for classes of 30 and above.

3. Section modulus in in³.

Table 68. *Logistical Data and Other Characteristics of Cableways and Tramways*

Type	Issue	Composition	Transportation	Capacity	Length	Construction	
						Personnel	Time
Medium cableway---	Class IV---	2 sectionalized towers 1 carriage 2 keepers 1 drive unit 1 hoist unit Accessories, tools, and tackle.	4 2½-ton trucks or 7 1½-ton trucks	Carrier load 3,000 pounds; approxi- mately 17 tons per hour, over 1,000 ft gap.	1,200 ft--	2 platoons--	5 hr.
Pioneer light aerial tramway and cableway, M1.	Class IV---	1 cableway carriage 6 tramway or cable- way carriages. 3 tramway carriers (7 ft). 1 drive unit 2 toboggans	1 2½-ton truck or	Tramway-carrier load 350 pounds.	2,000 ft--	2 platoons--	10 hr.
			2 1½-ton trucks or 9 ¼-ton trailers or	Cableway-carrier load 2,000 pounds approximately 10 fps.	1,500 ft--	1 platoon---	5 hr.
Light aerial tram- way, M2 (exten- sion set also avail- able).	Class IV---	1 lower terminal 1 upper terminal 12 intermediate towers. 1 power unit 4 carriers Accessories, tools, and tackle.	4 2½-ton trucks or	Carrier load 350 pounds approxi- mately 1 ton per hour over 3,000 ft length.	3,000 ft--	1 company-	24 hr.
			6 1½-ton trucks or 35 ¼-ton trucks or 35 ¼-ton trailers				

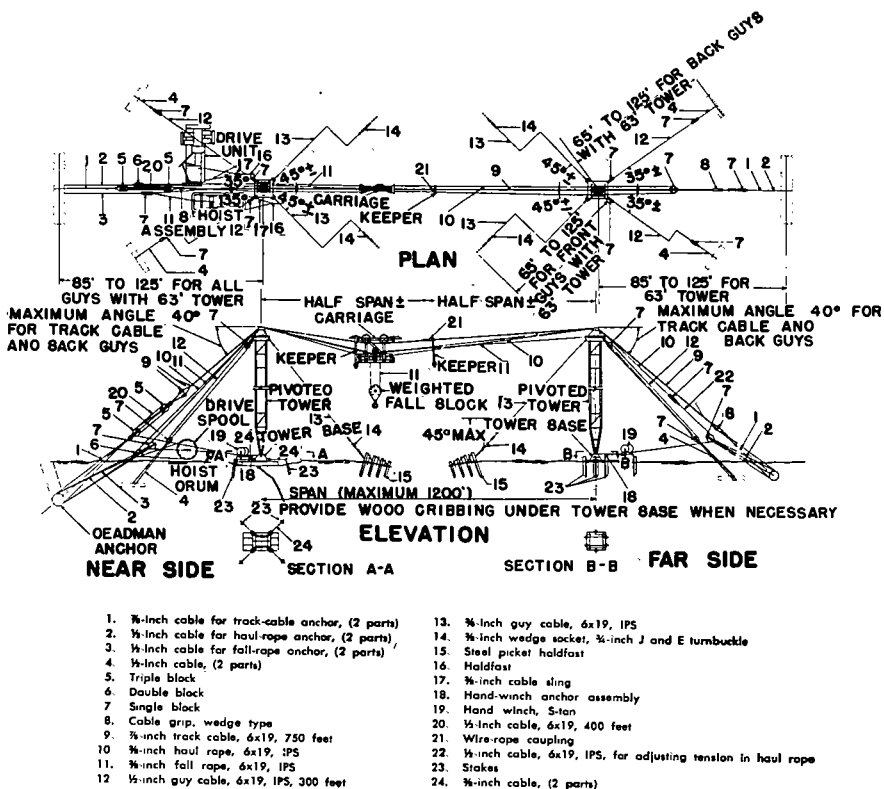


Figure 20. Medium cableway.



Figure 21. Pioneer tramway.

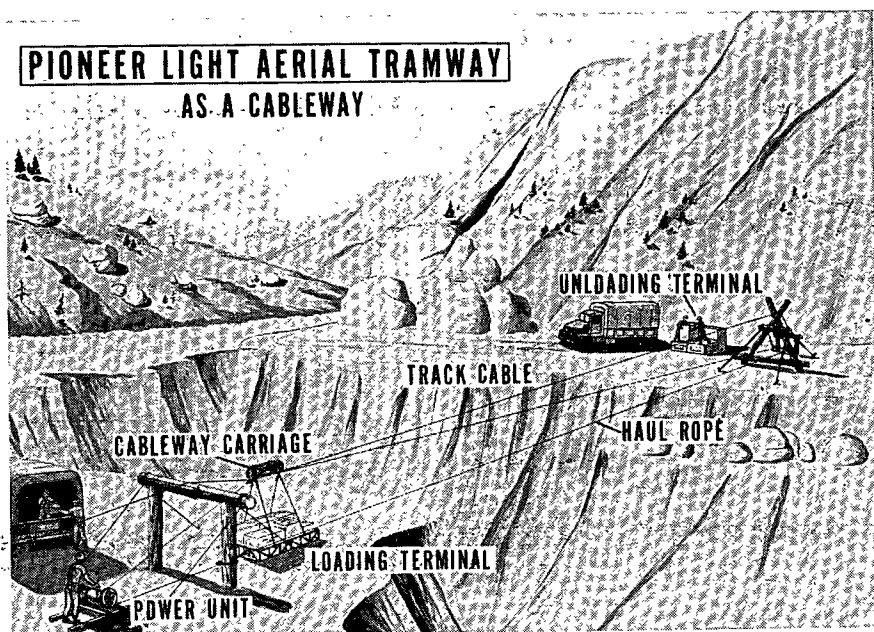


Figure 22. Pioneer cableway.

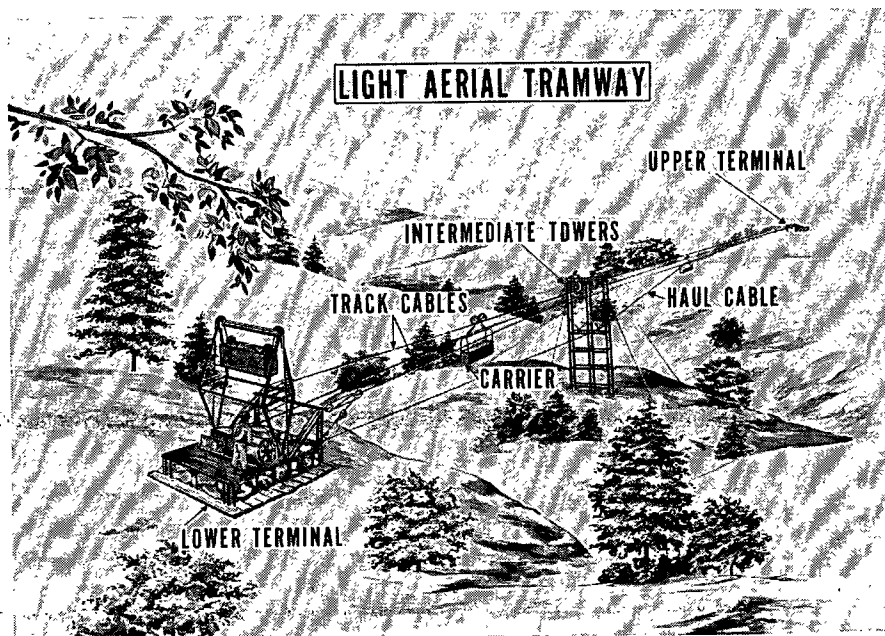


Figure 23. Light aerial tramway, M2.

CHAPTER 7

PONTOON GEAR

68. General

The Steel pontoons used consist of hollow steel boxes, designed to be assembled into floating structures of various sizes, shapes, and types. Full details are contained in Pontoon Gear Handbook, Navdocks TP-PL-7, Department of the Navy, Bureau of Yards and Docks.

69. Pontoons and Accessories

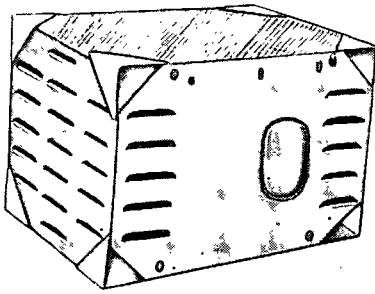
a. General. There are four types of pontoons, illustrated in figure 24 and described in *b* through *e* below.

b. The T6B or Rectangular Pontoon. The T6B is 5 feet $\frac{1}{2}$ inch by 7 feet in deck area and 5 feet $\frac{1}{2}$ inch deep. The side, end, deck, and bilge plating is $\frac{3}{16}$ inch thick. The deck is of checkered plate. Four 2-inch-diameter plugged holes are provided near the corners on one side plate for air, sea cocks, drain, or siphon connection. The pontoon weighs 2,000 pounds and has a volume of 175 cubic feet.

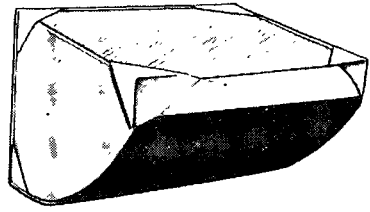
c. The T7A or Curved-Bilge Pontoon. The T7A has the same depth as the T6B, but it has a curved bilge and its deck is 7 feet square. The side, deck, and end plates are $\frac{3}{16}$ inch thick; the bilge plating is $\frac{1}{8}$ inch thick. The deck is of checkered plate. Four 2-inch-diameter plugged holes are provided in the side plate (the plate opposite the curved end). It is used for the curved bow and stern of barges. It weighs 2,800 pounds and has a volume of 189 cubic feet.

d. The T8 or Sloped-Deck Pontoon. The T8 is 5 feet $2\frac{3}{8}$ inches by 7 feet in deck area and is inclined. The depth is 4 feet $11\frac{1}{8}$ inches at one end and 3 feet 6 inches at the other. The bottom is horizontal. All the plating is $\frac{3}{16}$ inch thick. The deck is checkered. There are two 2-inch-diameter plugged holes in the deep end.

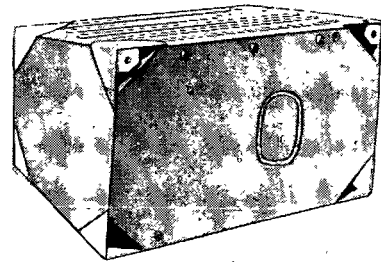
e. The T11 or Ramp-End Pontoon. The T11 has the same inclined-deck area as the T8. The offshore end is 3 feet 6 inches deep; the inshore end 1 foot. The bottom is horizontal for the first 1 foot 8 inches; and then pitches upward. The deck is $\frac{3}{16}$ inch checkered steel plate, the side and end plates $\frac{3}{16}$ inch plain, the bilge plating $\frac{1}{8}$ inch plain. The front vertical edges should be protected by welding on fenders consisting of half-sections of 6-inch steel pipe. There are two 2-inch-diameter plugged holes in the deep end.



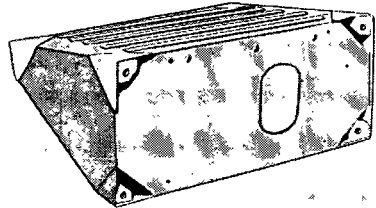
T6B, RECTANGULAR PONTOON.



T7A, CURVED-BILGE PONTOON.



T9, SLOPED-DECK PONTOON.



T11, RAMP-END PONTOON.

Figure 24. U.S. Navy pontoons.

f. Assembly Angles. The three standard sizes of steel assembly angles are 6 by 6 by $\frac{3}{8}$ inches, 6 by 6 by $\frac{1}{2}$ inches, and 8 by 8 by $\frac{1}{2}$ inches. In assembling pontoons, the size of angle used depends on the nature and size of the assembly and the rigidity required. The angles are fitted with wedge bars, to which the pontoons are attached by the jewelry, and with $\frac{1}{8}$ -turn breech-plug-slice end couplings for great lengths of assembly. Assembly angles can be altered by cutting and welding but cannot be improvised in the field because of the accuracy required in the spacing of the wedge bars.

g. Sets. The pontoons, assembly angles, jewelry, and other accessories and special parts are made up and shipped in standard sets for field assembly into barges, floating bridges, causeways, floating wharves, drydocks, and other structures.

70. Pontoon Assemblies (General)

The standard sets of pontoons and accessories can be assembled into floating units of various types and sizes. These include barges, floating bridges, causeways, floating wharves, drydocks, and other

structures. The practicability of any proposed assembly can be determined by making a parts list of the units needed and comparing it with the packing lists for standard sets as given in the Pontoon Gear Handbook.

71. Barges

a. Use. Pontoon barges can be used in a variety of situations as substitutes for ordinary rigid barges. They can also be equipped for use as cranes, piledrivers, drill rigs, and other special-purpose floating plant. If equipped with special inboard or outboard propulsion units, they can be used for icebreakers or tugboats.

b. Assembling. Normally, a string of pontoons of a length depending on the desired length of the barge is first assembled and launched. T7A pontoons are used for the ends and T6B for the rest of the string (fig. 25). Other strings are similarly assembled and launched, and the strings are then connected side by side to give a barge of the desired width. Assembly is by link-and-pin connection at the top angles and by tie rods near the bottom, as shown in figure 26. Installation of A13 deck-closure channels (8-inch ship channel, 18.7 pounds, 5 feet 10 $\frac{3}{4}$ inches long) as shown in figure 27 completes the assembly for standard purposes. Figure 27 also shows the method of determining the precise length of a string. Accessories to permit other types of closure and also cleats, chocks, bollards, bits, etc., are available in the standard sets.

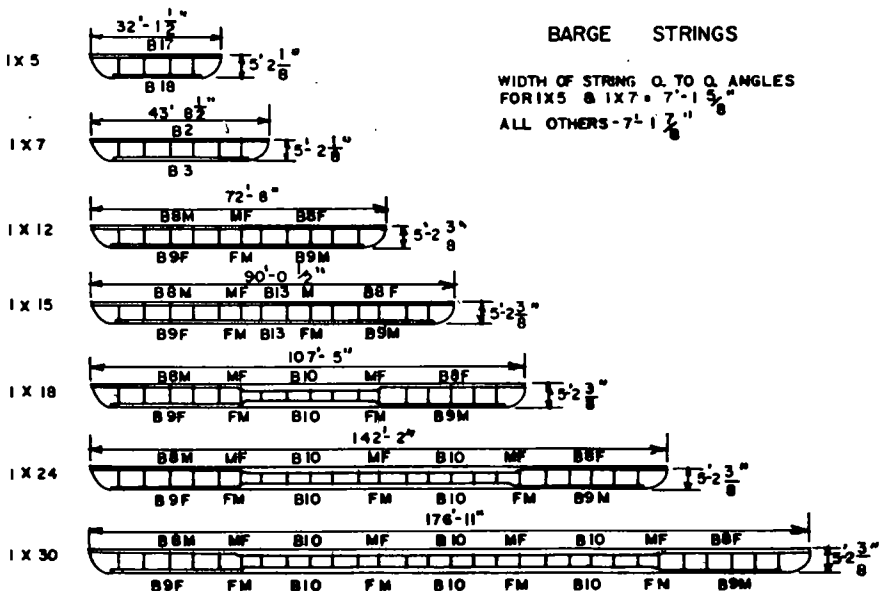


Figure 25. Side elevations of barge strings.

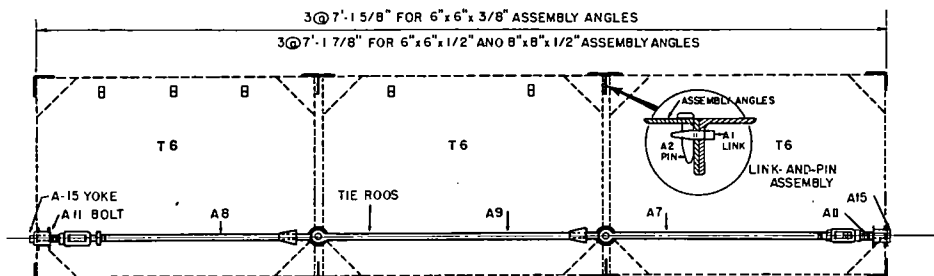


Figure 26. Lateral assembly of barge strings.

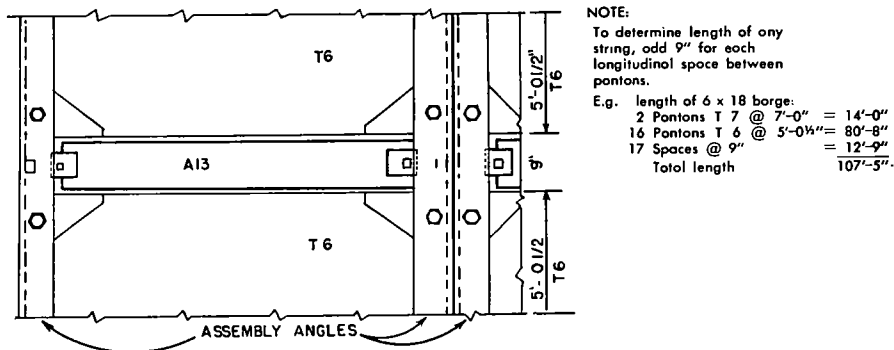


Figure 27. Deck-closure channels; determining length of string.

c. *Buoyancy and Capacity.* Pontoon barges up to 6 by 18, about 43 feet by 107 feet and rated at 250 tons with 48-inch draft, are designed to carry a load at the center point heavy enough to bring the deck awash. For longer barges, the maximum load the barge can float must be distributed over at least the center 6 pontoons of a 24-long barge and at least the center 12 pontoons of a 30-long floating structure. Table 69 shows the load capacities, in tons, of certain standard barge assemblies.

Table 69. Standard Barge Assemblies

Number of pontoons wide x long	Capacity (tons)	Nominal width and length (feet)	Draft	
			Light (inches)	Loaded (inches)
3 x 7	50	21 x 43	20	48
4 x 12	100	28 x 72	20	44
5 x 12	125	35 x 72	20	48
6 x 18	250	43 x 107	20	48
6 x 30	500	43 x 175	20	48

72. Bridges

a. Standard Bridge Units. The term "standard bridge unit" is normally applied by the Navy to an assembly of pontoons used to connect a floating pontoon wharf to the shore. Such units may also be used to bridge a waterway. The standard units are:

- (1) The 2-by-12 bridge unit, composed of 2 strings each containing 10 intermediate T6B and 2 end T7A pontoons.
- (2) The 4-by-18 bridge unit, composed of 4 strings each containing 16 intermediate T6B and 2 end T7A pontoons.

b. Bridge Strings. Strings of pontoons, known as bridge strings, are also used to bridge a waterway. Normally they are made of T6B pontoons. Figure 28 shows the side elevations of such bridge strings. Any desired width can be attained by assembling strings laterally.

c. Bridging a Waterway. The strings or units used for this purpose are assembled, launched, and floated into position. The bridge must be anchored and the approaches prepared, as in the case of Army pontoon equipment. Anchors are not provided with the standard sets. T8 and T11 pontoons may be used at the shore ends. To adjust the length of unit assemblies to the width of the river, strings or units may be lapped in midstream, care being taken to make the lap long enough for vehicles to negotiate (figs. 29 and 30). Acting as a beam, a 2-by-12 pontoon bridge, supported only at each end, will carry a 40-ton vehicle at its center.

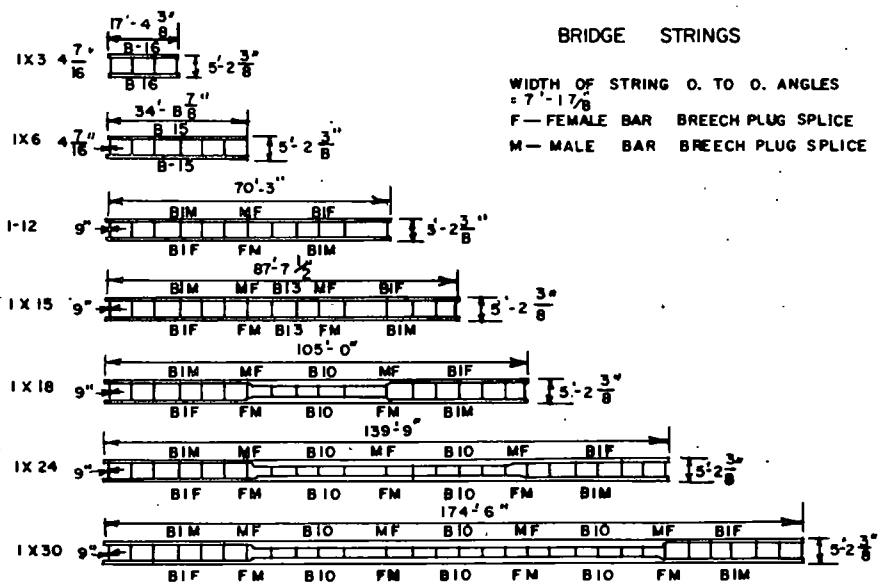


Figure 28. Side elevations of bridge strings.

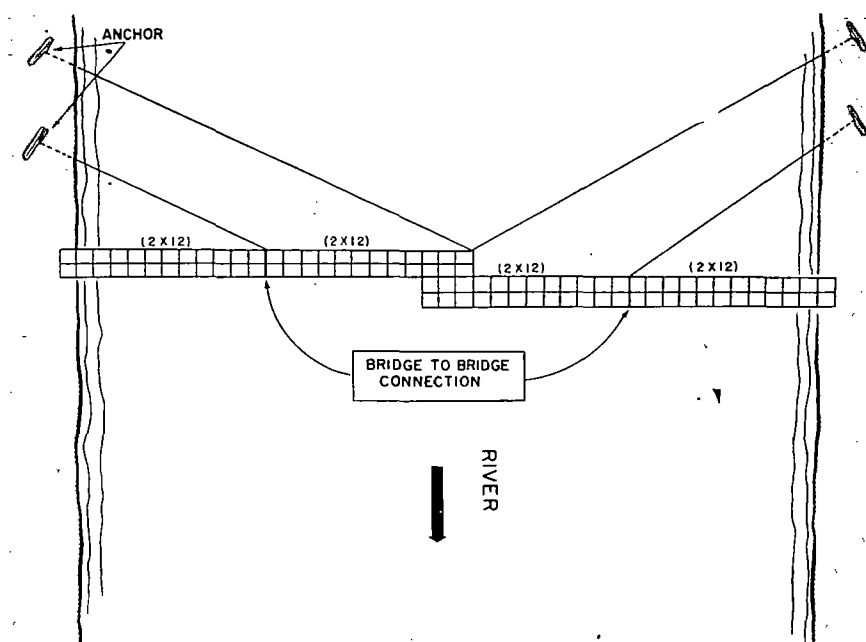


Figure 29. A bridge made of standard 2 by 12 units, lapped in midstream.

73. Standard Causeway

This assembly, made like a 2-by-30 barge, about 14 feet by 175 feet, is side-carried on LST's and launched to permit dry landings on flat beaches. The causeway units can be assembled later for other bridge, wharf, or barge purposes. End pontoons are T11.

74. Wharves

a. The standard sizes are 5 by 12, about 36 by 70 feet, and 7 by 60, about 50 feet by 350 feet. All pontoons are T6B.

b. Wharves 6 or more pontoons wide and 72 pontoons long, about 43 feet wide by 420 feet long, have been used satisfactorily for unloading cargo ships of Victory and Liberty type (fig. 31). To have adequate depth alongside, they must normally be moored offshore and fitted with bridge approaches. Three approaches, each 4 pontoons wide, are usually adequate.

c. In protected water with depths and bottom materials suitable for pile dolphins, there is no structural limitation on the size of either marginal or finger-pier floating wharves. Satisfactory moorings for such wharves have been developed by omitting one T6B pontoon at each corner and at intervals along the face and driving a pile cluster in each of the openings thus provided. The pile clusters also serve as ship moorings and as fenders to hold hulls away from the wharf.

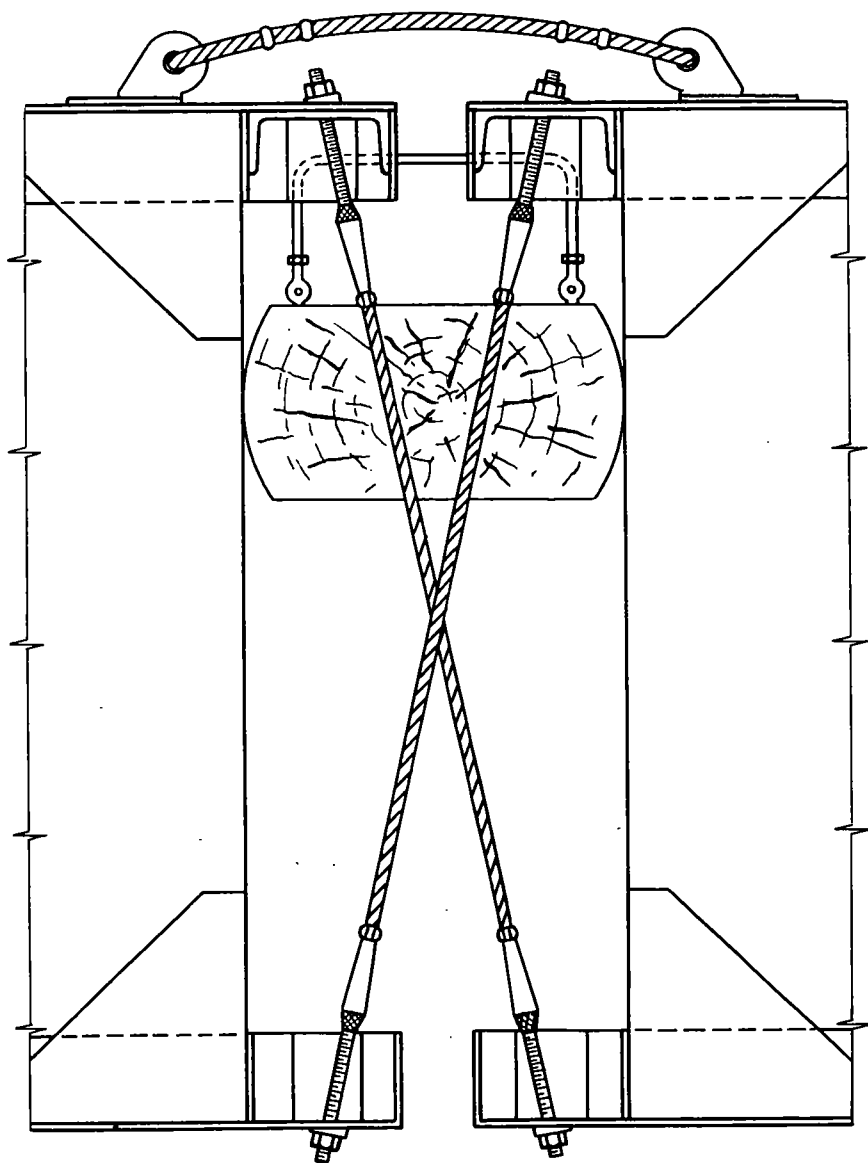


Figure 30. Bridge-to-bridge connection.

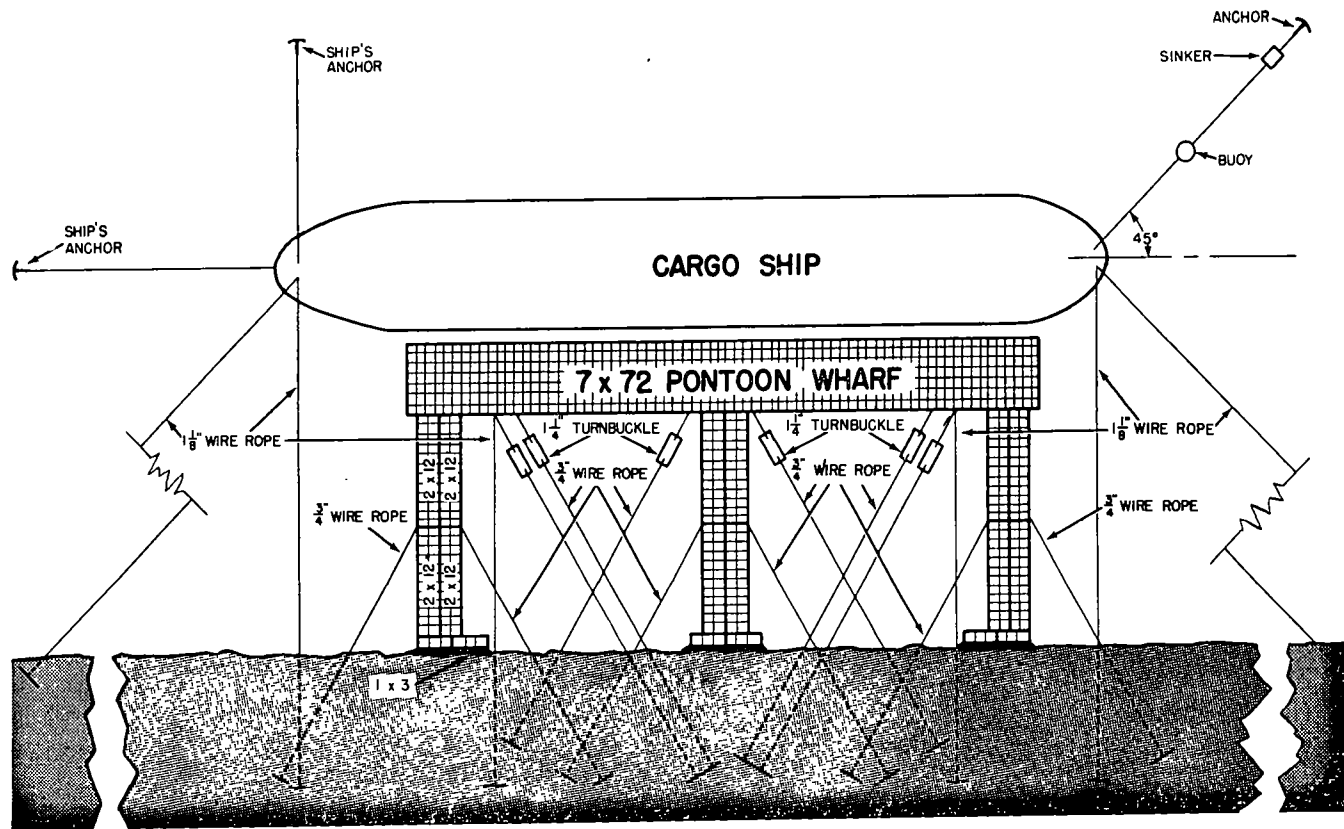


Figure 31. A 7-by-72 floating wharf, showing typical moorings.

CHAPTER 8

UTILITIES

Section I. WATER SUPPLY AND DISTRIBUTION

75. General

The water requirements of troops under various service conditions and the capacities of water-supply and distribution equipment are given in FM 101-10. Related publications dealing with specialized aspects of the problem are TM 5-295 and TM 5-297.

76. Responsibilities.

a. Unit Commander. It is the responsibility of the unit commander to provide units and individuals of his command with the required amount of safe drinking water at all times. He must make clear to every individual the danger in drinking unsafe water. He must enforce strict water discipline so that men—

- (1) Drink only treated or approved water.
- (2) Don't waste purified water.
- (3) Protect sources of water by good sanitary discipline.

b. Corps of Engineers. The Corps of Engineers is responsible for making available a supply of approved water for all purposes to all Army units. It is responsible for the design, procurement, installation, operation, and maintenance of water-supply equipment. In addition, it makes reconnaissances, develops sources, and transports water to distribution points. It works closely with the Army Medical Service to make certain that the water is safe to use.

c. Army Medical Service. The Army Medical Service determines whether or not the water is safe and makes recommendations to the proper authorities. The Army Medical Service inspects the water points and sources, tests the water, and works closely with the Corps of Engineers to make certain that the water is treated and distributed properly. In addition, the Army Medical Service studies and makes recommendations on the design and selection of water-purification equipment.

d. Chemical Corps. The Chemical Corps has responsibilities with respect to water-supply systems which have been contaminated by toxic agents.

77. Water Sources

When the sources of water in an area are free of unusual impurities, the following guide the selection of the source.

a. In populated areas, use established public systems to the fullest extent.

b. Use existing springs or wells next. The quality of water from these sources is usually better than from surface sources.

c. If public or ground-water sources are not readily available, use surface-water sources such as rivers, streams, lakes, or ponds, including flowing subsurface water in dry streambeds.

d. When other sources are not available, develop ground-water sources. Development of new ground-water sources is not practicable for an army on the move. For rear-echelon units, a ground-water source is usually best, especially in areas where surface-water sources are highly contaminated.

e. When no fresh-water source can be found, and sea water is available, use distillation units to purify the sea water.

f. In Arctic areas melt snow or ice to obtain water.

g. In general, every water source used by troops must be initially and periodically checked for contamination.

78. Water Consumption

Table 70 shows approximate figures for per-capita water demand by troops in a theater under various conditions. The figures are subject to considerable variation because of climate, terrain, physical condition of troops, water discipline, and other factors.

79. Measurement of Flow

a. Stream Flow. $Q=av$, where Q is quantity of water in cubic feet per second, a is area of cross section of stream in square feet, and v is average velocity of stream in feet per second. Determine a by estimate or measurement. Estimate v by measuring the velocity of a chip floating in midstream and multiplying this by 0.75.

b. Springs. Note the time required to fill a container of known capacity.

c. Wells. Pump the well at a rate nearly equal to the rate of flow into the well. Measure the amount obtained by flowing into a suitable vessel or compute the rate of flow by the use of figure 33 or 34.

d. Free-Flowing Artesian Wells. If the well discharges through a vertical pipe, measure the height of the jet and apply this measurement to figure 32.

Table 70. Daily Water Requirements

Unit consumer	Conditions of use	Gallons per unit consumer per day	Remarks
Man-----	In combat:		
	Minimum-----	$\frac{1}{2}$ -1-----	For periods not exceeding 3 days, when operational rations are used.
	Normal-----	2-----	When field rations are used.
		3-----	Drinking plus small amount for cooking or personal hygiene.
	March or bivouac--	2-----	Minimum for all purposes.
	Standard 4 and 5--	5-----	Desirable for all purposes (does not include bathing).
	Standard 4 and 5-- Standard 6-----	15----- 25-----	Includes allowance for waterborne sewage system.
Horse or mule---	Permanent camp--	100-----	
	Minimum-----	3-5-----	A horse can go for 48 hr. without water, drinks from 3 to 5 gals. at a watering, and requires 5 min. to drink.
	Normal-----	10-----	
Vehicle-----	Level and rolling country.	$\frac{1}{8}$ - $\frac{1}{2}$ -----	Depending on size of vehicle.
	Mountainous country.	$\frac{1}{4}$ -1-----	Depending on size of vehicle.
Locomotive-----	Standard military--	Variable----	150 gal. per trail mile.
	Commercial-----	Variable----	200 gal. per trail mile.
Hospital-----	With water-borne sewage.	50 per bed--	Includes water for medical personnel.

e. Rate of Flow in Full-Flowing Horizontal Pipe. To determine the rate of flow (in gallons per minute) from full-flowing horizontal pipes, use the formula illustrated in figure 33.

f. Discharge From Partially Filled Horizontal Pipe. To determine the rate of flow (in gallons per minute) from partially filled pipes divide the height of the fluid in the pipe (K, in inches) by the diameter (D, in inches). If K/D is between 0.2 and 0.6, apply the value to the alignment chart (fig. 34).

80. Pressure and Discharge Tables

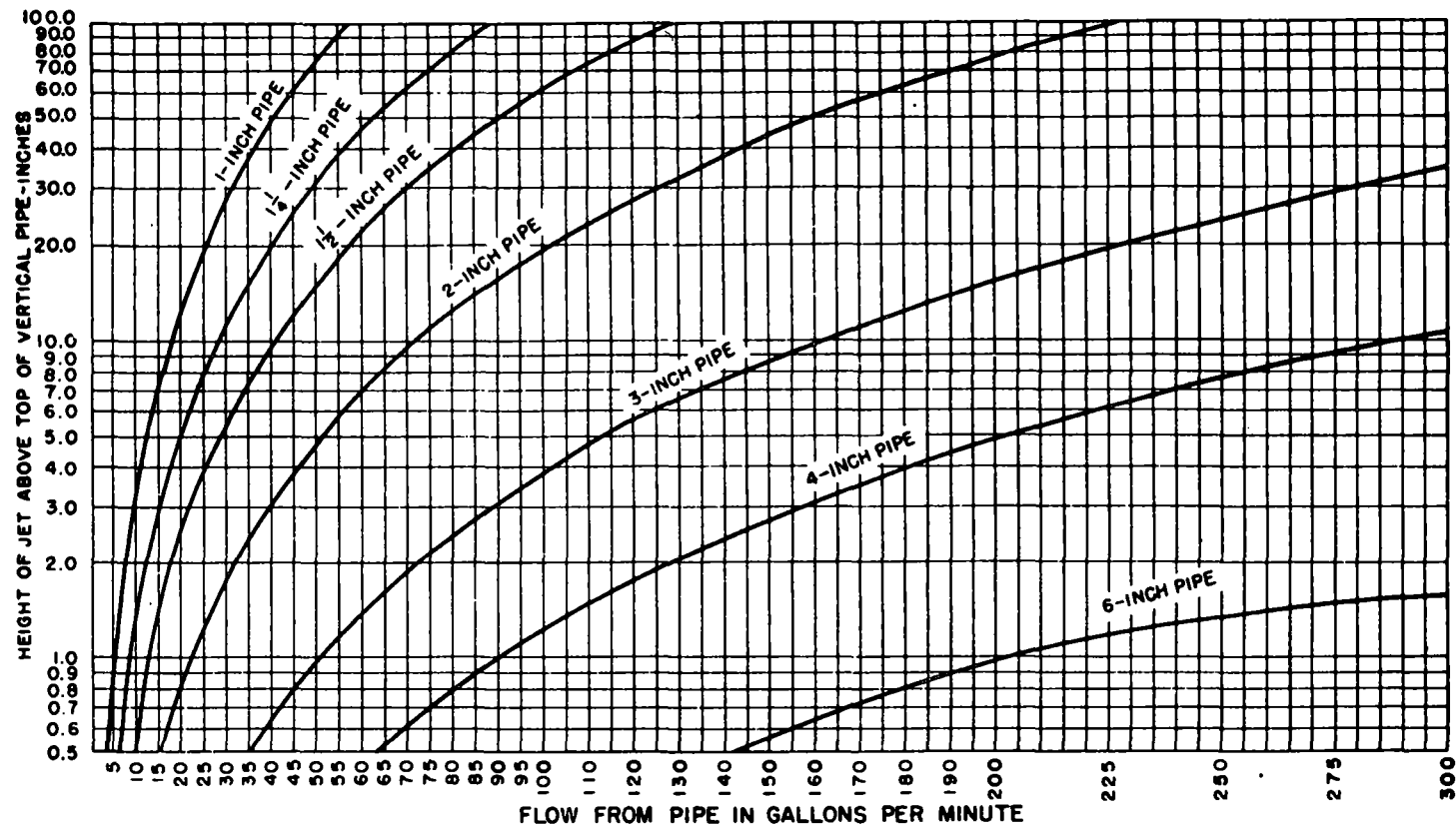
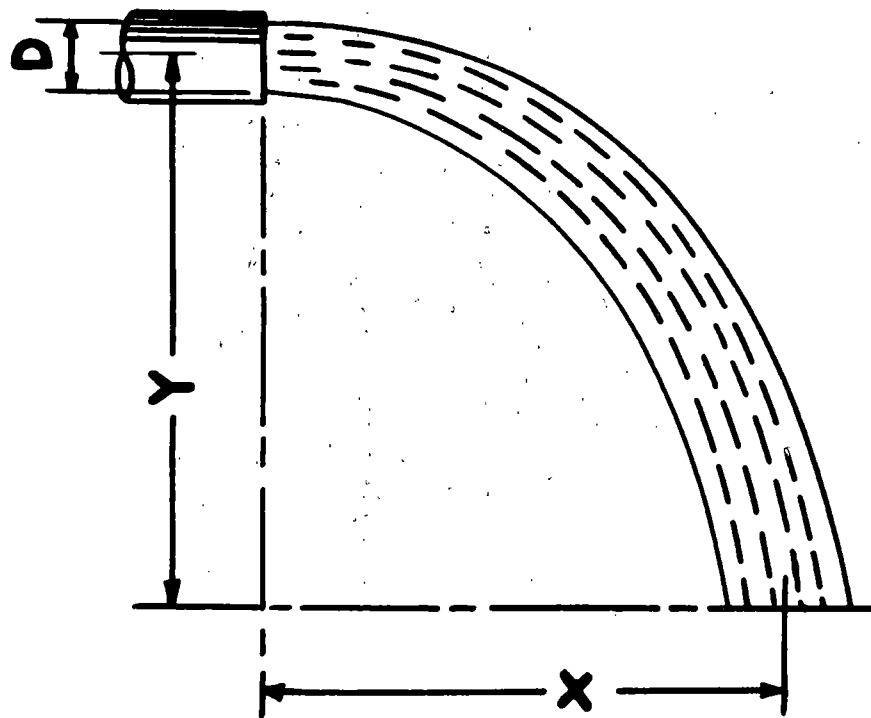


Figure 32. Flow from artesian well—vertical well pipe.



NOTE. Jet must be full flowing; no contraction or enlargement.

$$\text{Flow in gpm} = \frac{2.83 \cdot D^2 \cdot X}{\sqrt{Y}}$$

D = Inside diameter of pipe

X = Horizontal distance in inches

Y = Vertical distance in inches

Example using formula:

Given: A 3-inch-diameter standard pipe
(D = 3.07") held 16 inches from ground
(Y = 16"); X determined by measurement
(X = 28").

$$\frac{2.83 \cdot 3.07^2 \cdot 28}{\sqrt{16}} = \frac{2.83 \cdot 9.4 \cdot 28}{4} = 187 \text{ gpm}$$

Figure 38. Flow from full-flowing horizontal pipe.

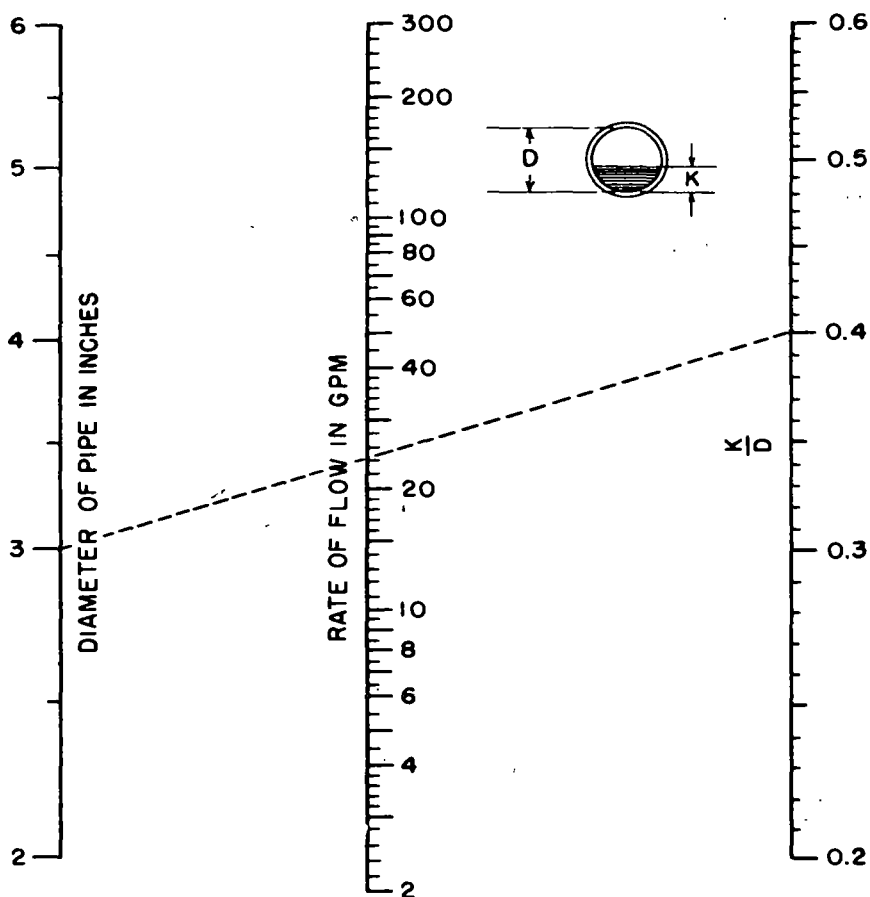


Figure 34. Flow from partially filled horizontal pipe; good for K/D values between 0.2 and 0.6.

Table 71. Flow of Water (Gallons Per Minute) Through Smooth-Bore Hose ¹

Hose (internal diameter inches)	Water pressure, pounds per square inch									
	20	30	40	50	60	70	80	90	100	125
1.00-----	23	28	33	37	40	43	46	49	52	58
1.25-----	40	50	57	64	70	76	81	86	90	101
1.50-----	64	78	90	101	111	120	128	135	143	159
2.00-----	130	159	184	206	227	242	262	275	292	326
2.50-----	226	278	322	358	394	425	455	482	509	566
3.00-----	356	437	504	570	620	665	715	755	800	890
4.00-----	745	910	1, 055	1, 180	1, 292	1, 395	1, 492	1, 582	1, 670	1, 850

¹ Data shown are based on 100-foot length of hose, laid in a straight line with open discharge end. For each set of couplings, deduct 5 percent.

Table 72. Suction Lift of Pumps at Various Altitudes

Altitude above sea level		Barometric pressure (pounds per square inch)	Equivalent head of water (feet)	Practical suction lift of pump (feet)
Feet	Miles			
0-----	0	14. 70	33. 95	25
1,320-----	¼	14. 02	32. 38	24
2,640-----	½	13. 33	30. 79	23
3,960-----	¾	12. 66	29. 24	21
5,280-----	1	12. 02	27. 76	20
6,600-----	1¼	11. 42	26. 38	19
7,920-----	1½	10. 88	25. 13	18
10,560-----	2	9. 88	22. 82	17

Table 73. Theoretical Discharge of Nozzles in United States, Gallons Per Minute ¹

Head		Velocity of discharge (feet per second)	Diameter of nozzle in inches									
Psi	Feet		$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
10.....	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23.6	36.9	53.1	72.4	94.5
15.....	34.6	47.25	.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5	116.0
20.....	46.2	54.55	.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102.0	134.0
25.....	57.7	61.0	.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114.0	149.0
30.....	69.3	66.85	.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125.0	164.0
35.....	80.8	72.2	.69	2.77	6.21	11.1	24.8	44.2	69.0	99.5	135.0	177.0
40.....	92.4	77.2	.74	2.96	6.64	11.8	26.6	47.3	73.6	106.0	145.0	189.0
45.....	103.9	81.8	.78	3.13	7.03	12.5	28.2	50.1	78.2	113.0	153.0	200.0
50.....	115.5	86.25	.83	3.30	7.41	13.2	29.7	52.8	85.5	119.0	162.0	211.0
55.....	127.0	90.4	.87	3.46	7.77	13.8	31.1	55.3	86.4	125.0	169.0	221.0
60.....	138.6	94.5	.90	3.62	8.12	14.5	32.5	57.8	90.4	130.0	177.0	231.0
65.....	150.1	98.3	.94	3.77	8.45	15.1	33.8	60.2	94.0	136.0	184.0	241.0
70.....	161.7	102.1	.98	3.91	8.78	15.7	35.2	62.5	97.7	141.0	191.0	250.0
75.....	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101.0	146.0	198.0	259.0
80.....	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104.0	150.0	205.0	267.0
85.....	196.3	112.5	1.08	4.31	9.67	17.3	38.8	68.9	108.0	155.0	211.0	276.0
90.....	207.9	115.8	1.11	4.43	9.95	17.7	39.9	70.8	111.0	160.0	217.0	284.0
95.....	219.4	119.0	1.14	4.56	10.2	18.2	41.0	72.8	114.0	164.0	223.0	292.0
100.....	230.9	122.0	1.17	4.67	10.05	18.7	42.1	74.7	117.0	168.0	229.0	299.0

¹ The actual quantities will vary from the figures in this table, depending on the shape of the nozzle and the size of the pipe at the point where the pressure is determined.

With smooth-taper nozzles the actual discharge is about 94 percent of the figures given in the table above.

Table 74. Maximum Quantities of Water in Gallons Per Minute Which Can Be Pumped Through 100 Feet of Wrought-Iron Pipe at Various Pressures

Pressure	Pipe diameter (inches)								
	½	¾	1	1¼	1½	2	2½	3	4
17 psi-----	3. 2	9. 1	18. 7	33. 5	51. 6	106	200	290	589
30 psi-----	5. 0	14. 0	28. 0	52. 0	78. 0	160	308	436	885
40 psi-----	6. 0	16. 0	33. 0	60. 0	90. 0	184	350	504	1, 023
50 psi-----	6. 5	17. 5	37. 0	70. 0	101. 0	206	390	564	1, 143
60 psi-----	7. 0	19. 5	40. 0	76. 0	110. 0	226	430	617	1, 252
75 psi-----	7. 5	22. 0	45. 0	85. 0	123. 0	253	480	690	1, 400
100 psi-----	9. 0	25. 0	52. 0	99. 0	142. 0	292	558	797	1, 607

Table 75. *Relative Equivalent Quantities of Water Delivered*

Gallons in 1 minute	Gallons in 1 hour	Gallons in 24 hours	Gallons in 1 minute	Gallons in 1 hour	Gallons in 24 hours	Gallons in 1 minute	Gallons in 1 hour	Gallons in 24 hours
3. 4	208	5, 000	138. 8	8, 333	200, 000	486. 1	29, 166	700, 000
6. 9	416	10, 000	173. 6	10, 416	250, 000	520. 8	31, 250	750, 000
10. 4	625	15, 000	208. 3	12, 500	300, 000	555. 5	33, 333	800, 000
13. 8	833	20, 000	243. 0	14, 583	350, 000	590. 2	35, 416	850, 000
17. 3	1, 041	25, 000	277. 7	16, 666	400, 000	625. 0	37, 500	900, 000
34. 7	2, 083	50, 000	312. 5	18, 750	450, 000	659. 7	39, 583	950, 000
41. 6	2, 500	60, 000	347. 2	20, 833	500, 000	694. 3	41, 666	1, 000, 000
52. 9	3, 125	75, 000	381. 9	22, 916	550, 000	1, 041. 7	62, 500	1, 500, 000
69. 4	4, 166	100, 000	416. 7	25, 000	600, 000	1, 388. 0	83, 333	2, 000, 000
104. 1	6, 250	150, 000	451. 3	27, 083	650, 000	1, 736. 0	104, 166	2, 500, 000

81. Rate of Flow Equivalents

See table 76.

82. Volume and Capacity Equivalents

See table 77.

83. Head-Pressure Conversion Factors

The head of water in feet and the resultant static pressure in p.s.i. (pounds per square inch) are related as follows:

$$\text{Pressure} = \text{head} \times 0.4331$$

$$\text{Head} = \text{pressure} \times 2.31.$$

84. Loss of Head in 1½-Inch Hose

For various flows in gallons per minute, the loss of head per hundred feet of 1½-inch hose is given in figure 35.

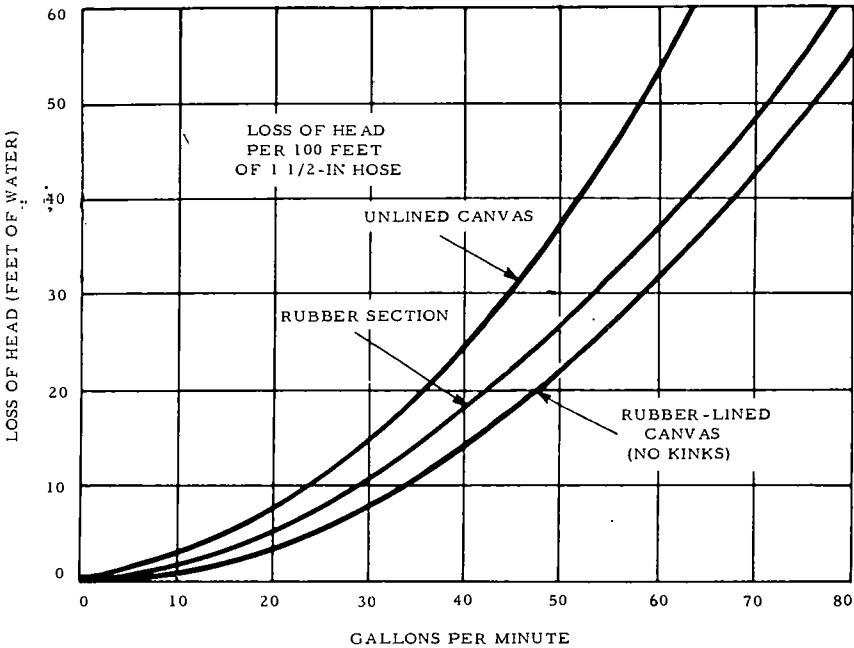


Figure 35. Loss of head in 1½-inch hose.

Table 76. Rate of Flow Equivalents

Units	Cubic feet per second	Cubic feet per minute	U.S. gallons per minute	U.S. gallons per 24 hr.
1 cubic foot per second equals.....	1. 0	60. 0	448. 83	646, 317. 0
1 cubic foot per minute equals.....	0. 02	1. 0	7. 48	10, 771. 9
1 U.S. gallon per minute equals.....	0. 002	0. 13	1. 0	1, 440. 0
1 U.S. gallon per 24 hours equals.....	1. 55×10 ⁻⁶	9. 28×10 ⁻⁵	0. 0007	1. 0
1 British Imperial gallon per minute equals.....	0. 003	0. 16	1. 20	1, 729. 37
1 liter per minute equals...	0. 0006	0. 03	0. 26	380. 42
1 acre-foot per hour equals...	12. 1	726. 0	5, 430. 86	7, 820, 434. 0
1 acre-foot per 24 hours equals.....	0. 50	30. 25	226. 2	325, 851. 0

Units	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hr.
1 cubic foot per second equals.....	373. 3	1, 698. 98	0. 083	1. 98
1 cubic foot per minute equals.....	6. 23	28. 32	0. 001	0. 03
1 U.S. gallon per minute equals.....	0. 83	3. 78533	0. 0001841	0. 0044192
1 U.S. gallon per 24 hours equals.....	0. 000	0. 003	1. 28×10 ⁻⁷	3. 07×10 ⁻⁵
1 British Imperial gallon per minute equals.....	1. 0	4. 55	0. 0002	0. 005
1 liter per minute equals...	0. 22	1. 0	4. 86×10 ⁻⁵	0. 001
1 acre-foot per hour equals...	4, 522. 13	20, 557. 6	1. 0	24. 0
1 acre-foot per 24 hours equals.....	188. 42	856. 57	0. 04	1. 0

Note. Negative exponents to the number 10 indicate the number of decimal places to the right of the decimal point, i.e.: 10⁻⁶=0.000001; 10⁻³=0.001; 1.55×10⁻⁶=0.00000155.

Table 77. Volume and Capacity Equivalents

Units	U.S. gallons	British Imperial gallons	Liters
1 U.S. gallon equals	1. 0	0. 83	3. 78
1 British Imperial gallon equals	1. 20	1. 0	4. 55
1 liter equals	0. 26	0. 22	1. 0
1 cubic foot equals	7. 48	6. 23	28. 32
1 cubic inch equals	4. 33	$3. 6 \times 10^{-3}$	0. 02
1 acre-foot equals	325851. 0	271, 328. 0	1, 233, 456. 0
1 inch deep on 1 acre equals	27154. 3	22, 610. 6	102, 788. 0
1 inch deep on 1 square mile equals	17, 378, 743. 0	14, 470, 801. 0	65, 784, 344. 0
1 meter deep on 1 hectare equals	2, 641, 705. 0	2, 199, 675. 0	9, 999, 734. 0
1 centimeter deep on 1 square meter equals	2. 64	2. 20	10. 0
1 pound of water at 39.2° F. equals	0. 02	0. 10	0. 45
1 pound of water at 50° F. equals	0. 12	0. 10	0. 45
1 pound of water at 62° F. equals	0. 12	0. 10	0. 45
1 U.S. gallon per minute for 24 hours equals	1, 440. 0	1, 199. 05	5, 450. 88
1 cubic foot per minute for 24 hours equals	10, 771. 9	8, 969. 50	40, 775. 4

See note at end of table.

Table 77. Volume and Capacity Equivalents—Continued

Units	Cubic feet	Cubic inches	Acre-feet
1 U.S. gallon equals----	0. 13	231. 0	$3. 07 \times 10^{-6}$
1 British Imperial gal- lon equals-----	0. 16	277. 42	$3. 69 \times 10^{-6}$
1 liter equals-----	0. 03	61. 02	$8. 11 \times 10^{-7}$
1 cubic foot equals----	1. 0	1, 728. 0	$2. 296 \times 10^{-5}$
1 cubic inch equals----	$5. 79 \times 10$	1. 0	$1. 33 \times 10^{-8}$
1 acre-foot equals----	43, 560. 0	75, 271, 680. 0	1. 0
1 inch deep on 1 acre equals-----	3, 630. 0	6, 272, 640. 0	0. 08
1 inch deep on 1 square mile equals-----	2, 323, 200. 0	4, 014, 489, 600. 0	53. 33
1 meter deep on 1 hectare equals-----	353, 145. 0	610, 233, 780. 0	8. 10708
1 centimeter deep on 1 square meter equals--	0. 35	610. 23	$8. 11 \times 10^{-6}$
1 pound of water at 39.2° F. equals-----	0. 02	27. 68	$3. 69 \times 10^{-7}$
1 pound of water at 50° F. equals-----	0. 02	27. 69	$3. 68 \times 10^{-7}$
1 pound of water at 62° F. equals-----	0. 02	27. 71	$3. 68 \times 10^{-7}$
1 U.S. gallon per minute for 24 hours equals---	192. 5	332, 640. 0	0. 004
1 cubic foot per minute for 24 hours equals---	1. 440. 0	2, 488, 320. 0	0. 03

Note. Negative exponents to the number 10 indicate the number of decimal places to the right of the decimal point, i.e.: $10^{-6}=0.000001$; $10^{-3}=0.001$; $1.55 \times 10^{-6}=0.00000155$.

85. Vertical Cylindrical Tank Capacities

Capacities per foot of depth for vertical cylindrical tanks 1 foot to 100 feet in diameter are shown in table 78. Capacities per inch of depth may be computed by dividing the values shown by 12.

86. Chemicals Used to Coagulate or Adjust Alkalinity of Water

See table 79.

87. Water Supply and Distribution Systems

a. Function. A water system consists of a well, spring, river, lake, reservoir, or other water source; the treatment plant, pump, ground or elevated storage tanks, supply lines, or other production and treatment facilities; and the distribution lines which convey the approved water to the various outlets.

b. Description.

(1) *Basic systems.* There are three basic types of water supply and distribution systems.

(a) Gravity flow, where the source is at sufficient elevation above the outlets to transport the water without pumping.

Table 78. Vertical Cylindrical Tank Capacities

Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth	Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth
1' 0''	0.785	5.87	4' 4''	14.75	110.3
1' 1''	0.922	6.89	4' 5''	15.32	114.6
1' 2''	1.069	8.00	4' 6''	15.90	119.0
1' 3''	1.227	9.18	4' 7''	16.50	123.4
1' 4''	1.396	10.44	4' 8''	17.10	128.0
1' 5''	1.576	11.79	4' 9''	17.72	132.6
1' 6''	1.767	13.22	4' 10''	18.35	137.3
1' 7''	1.969	14.73	4' 11''	18.99	142.0
1' 8''	2.182	16.32	5'	19.63	146.9
1' 9''	2.405	17.99	5' 3''	21.65	161.9
1' 10''	2.640	19.75	5' 6''	23.76	177.7
1' 11''	2.885	21.58	5' 9''	25.97	94.3
2'	3.142	23.50	6'	28.27	211.5
2' 1''	3.409	25.50	6' 3''	30.68	229.5
2' 2''	3.687	27.58	6' 6''	33.18	248.2
2' 3''	3.976	29.74	6' 9''	35.78	267.7
2' 4''	4.276	31.99	7'	38.48	287.9
2' 5''	4.587	34.31	7' 3''	41.28	308.8
2' 6''	4.909	36.72	7' 6''	44.18	330.5
2' 7''	5.241	39.21	7' 9''	47.17	352.9
2' 8''	5.585	41.78	8'	50.27	376.0
2' 9''	5.940	44.43	8' 3''	53.46	399.9
2' 10''	6.305	47.16	8' 6''	56.75	424.5
2' 11''	6.681	49.98	8' 9''	60.13	449.8
3'	7.069	52.88	9'	63.62	475.9
3' 1''	7.467	55.86	9' 3''	67.62	502.7
3' 2''	7.867	58.92	9' 6''	70.88	530.2
3' 3''	8.296	62.06	9' 9''	74.66	558.5
3' 4''	8.727	65.28	10'	78.54	587.5
3' 5''	9.168	68.58	10' 6''	86.59	647.7
3' 6''	9.621	71.97	11'	95.03	710.9
3' 7''	10.08	75.44	11' 6''	103.9	777.0
3' 8''	10.56	78.99	12'	113.1	846.0
3' 9''	11.04	82.62	12' 6''	122.7	918.0
3' 10''	11.54	86.33	13'	132.7	992.9
3' 11''	12.05	90.13	13' 6''	143.1	1,071.0
4'	12.57	94.00	14'	153.9	1,152.0
4' 1''	13.10	97.96	14' 6''	165.1	1,235.0
4' 2''	13.64	102.0	15'	176.7	1,322.0
4' 3''	14.19	106.1	15' 6''	188.7	1,412.0

Table 78. Vertical Cylindrical Tank Capacities—Continued

Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth	Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth
16'	201. 1	1, 504. 0	38'	1, 134. 0	8, 483. 0
16' 6''	213. 8	1, 600. 0	39'	1, 195. 0	8, 940. 0
17'	227. 0	1, 698. 0	40'	1, 257. 0	9, 404. 0
17' 6''	240. 5	1, 799. 0	41'	1, 320. 0	9, 876. 0
18'	254. 5	1, 904. 0	42'	1, 385. 0	10, 360. 0
18' 6''	268. 8	2, 011. 0	43'	1, 452. 0	10, 860. 0
19'	283. 5	2, 121. 0	44'	1, 521. 0	11, 370. 0
19' 6''	298. 6	2, 234. 0	45'	1, 590. 0	11, 900. 0
20'	314. 2	2, 350. 0	46'	1, 662. 0	12, 430. 0
20' 6''	330. 1	2, 469. 0	47'	1, 735. 0	12, 980. 0
21'	346. 4	2, 591. 0	48'	1, 810. 0	13, 540. 0
21' 6''	363. 1	2, 716. 0	49'	1, 886. 0	14, 110. 0
22'	380. 1	2, 844. 0	50'	1, 964. 0	14, 690. 0
22' 6''	397. 6	2, 947. 0	52'	2, 124. 0	14, 890. 0
23'	415. 5	3, 108. 0	54'	2, 290. 0	17, 130. 0
23' 6''	433. 7	3, 245. 0	56'	2, 463. 0	18, 420. 0
24'	452. 4	3, 384. 0	58'	2, 642. 0	19, 760. 0
24' 6''	471. 4	3, 527. 0	60'	2, 827. 0	21, 150. 0
25'	490. 9	3, 672. 0	62'	3, 019. 0	22, 380. 0
25' 6''	510. 7	3, 820. 0	64'	3, 217. 0	24, 060. 0
26'	530. 9	3, 972. 0	66'	3, 421. 0	25, 590. 0
26' 6''	551. 5	4, 126. 0	68'	3, 632. 0	27, 170. 0
27'	572. 6	4, 283. 0	70'	3, 488. 0	28, 790. 0
27' 6''	594. 0	4, 443. 0	72'	4, 072. 0	30, 450. 0
28'	615. 8	4, 606. 0	74'	4, 301. 0	32, 170. 0
28' 6''	637. 9	4, 772. 0	76'	4, 536. 0	33, 930. 0
29'	660. 5	4, 941. 0	78'	4, 778. 0	35, 740. 0
29' 6''	683. 5	5, 113. 0	80'	5, 027. 0	37, 600. 0
30'	706. 9	5, 288. 0	82'	5, 281. 0	39, 500. 0
31'	754. 8	5, 646. 0	84'	5, 542. 0	41, 540. 0
32'	804. 3	6, 016. 0	86'	5, 809. 0	43, 450. 0
33'	855. 3	6, 398. 0	88'	6, 082. 0	45, 490. 0
34'	907. 9	6, 792. 0	90'	6, 362. 0	47, 590. 0
35'	962. 1	7, 197. 0	92'	6, 648. 0	49, 720. 0
36'	1, 018. 0	7, 616. 0	94'	6, 940. 0	51, 920. 0
37'	1, 075. 0	8, 043. 0	96'	7, 238. 0	54, 140. 0
			98'	7, 543. 0	56, 420. 0
			100'	7, 854. 0	58, 750. 0

Table 79. Chemicals Used to Coagulate or Adjust Alkalinity of Water

Chemical	How to use	How shipped	Weight (pounds per cubic foot)	Effective pH range	Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant	Artificial alkalinity re- quired in grains per gallon to react with 1 grain per gallon of co- agulant			Remarks
						Hydrated lime	Quick- lime	Soda ash	
Alum— $\text{Al}_2(\text{SO}_4)_3$ 18 H_2O .	Coagulant.....	100-pound bags..... 200-pound bags. 400-pound barrels. Bulk.	39.....	4.4 to 6.0.. 5.7 to 8.0. 9.0 to 10.5.	0.45	0.35	0.28	0.48	4.4 to 6.0 pH range used for highly colored water. 5.7 to 8.0 pH range used for turbid and moderately colored water. 9.0 to 10.5 pH range used in alum coagulation of carbonates in lime-soda softening.
Ammonia alum— $\text{Al}_2(\text{SO}_4)_3$ (NH_4) $_2\text{SO}_4$. 24 H_2O .	Coagulant.....	400-pound bags..... 100-pound kegs.	39±.....	5.7 to 8.0..	0.29±	0.23±	0.18±	0.31±	Less soluble than filter alum and weighs 1½ times as much in terms of aluminum oxide content. Use generally restricted to pressure filters incorporating an "alum pot" or in batch coagulation. Ammonia available for formation of chloramines.
Sulfuric acid— H_2SO_4 .	To adjust pH in connection with coagulation.	10-gallon carboys. 500-pound steel drums. 93%. 1,500-pound steel H_2SO_4 drums	Liquid: 18 pounds per gallon.	-----	-----	-----	-----	-----	Always dilute by adding acid to water, otherwise serious burns may result. Can be fed by use of hypochlorite-solution equipment.

See footnotes at end of table.

Table 79. Chemicals Used to Coagulate or Adjust Alkalinity of Water—Continued

Chemical	How to use	How shipped	Weight (pounds per cubic foot)	Effective pH range	Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant	Artificial alkalinity re- quired in grains per gallon to react with 1 grain per gallon of co- agulant			Remarks
						Hydrated lime	Quick- lime	Soda ash	
Sodium aluminate— $\text{Na}_2\text{Al}_2\text{O}_4$.	Coagulant.....	Solid: 108-pound thin- steel drums. 405-pound thin- steel drums. 100-pound bags. Liquid: 32% $\text{Na}_2\text{Al}_2\text{O}_4$ — steel drums 10% NaOH .	58±.....	6.0 to 7.5 (with alum).	.....	.....	.....	.....	Used with alum to assist in the coagulation of cold water. Also used with alum to coagulate alkaline waters, such as with water softening. Supplies alkali as well as aluminum. Commercial grade contains 55% aluminum oxide and 35% combined soda plus 6% excess caustic soda.
Copperas (ferrous sulfate)— FeSO_4 .	Coagulant.....	100-pound bags..... 200-pound bags. 400-pound barrels. Bulk.	46±.....	8.5 to 11.0.	.....	0.27	0.22	(1)	
Chlorinated copperas.	Coagulant.....	See copperas.....	See Copperas	3.5 to 9.5..	0.85	20.65	0.52	(1)	Chlorine added to copperas. One pound of chlorine required for each 7.8 pounds of copperas used.
Ferrie sulfate— $\text{Fe}_2(\text{SO}_4)_3$.	Coagulant.....	200-pound bags..... 400-pound wooden barrels.	70.....	3.5 to 9.5..	0.78	0.58	0.46	(1)	If dry-foot machine is used, must have solution pot feeding two parts water to each part of ferrie sulfate. Used with lime for iron and manganese removal.

Ferrie ebloride— FeCl ₃ .	Coagulant.....	Liquid: 12-gallon earboys. 42%. 8,000-gallon rubber-lined tank ears. 42%. Crystals: 55-gallon hard wood barrels, each containing 435 pounds. 60%. Anhydrous: 100 one pound bags per steel drum. 95% ferrie ebloride.	-----	3.5 to 9.5..	0.92	0.72	0.58	(1)	Very corrosive. Rubberlined equipment must be used. Use with lime for iron and manganese removal. Use with pulverized limestone to coagulate turbid and colored waters.
Soda ash—Na ₂ CO ₃ ..	To adjust pH, aid coagulation, or remove permanent hardness.	100-pound bags..... 200-pound bags. 400-pound barrels. Bulk.	63.....	-----	-----	-----	-----	-----	Readily soluble and non-corrosive to wrought-iron or lead piping. May be used to prevent corrosion when hardness of water exceeds about 40 quarts per million.
Hydrated lime— Ca(OH) ₂ .	To adjust pH, aid coagulation, or remove carbonate hardness.	50-pound paper bags..	50.....	-----	-----	-----	-----	-----	Only slightly soluble and thus is fed as a suspension. Cheaper and more effective than soda ash. Used to prevent corrosion irrespective of hardness of water.
Quick lime—CaO...	To adjust pH, aid coagulation, or remove carbonate hardness.	Wooden barrels, metal drums, water proof bags. Bulk.	65.....	-----	-----	-----	-----	-----	Must be slaked before used. Somewhat cheaper and more effective than hydrated lime, but difficulty of handling limits its use to large plants.
Pulverised limestone—94% CaCO ₃ .	Adjust pH and/or aid coagulation.	80-pound bags or bulk.	100.....	-----	-----	-----	-----	-----	May be added as batch or fed with dry or slurry feeders. Particularly useful in solids, contact reactors.

¹ Not normally used.

² See ferrie coagulants.

- (b) Direct pumping, where water from the source is pumped directly into the system with or without a pressure tank to absorb differences between pumping and usage rates.
 - (c) A combination of gravity and pumping, where water from the source is pumped to an elevated storage tank and from there distributed to the outlets by gravity.
- (2) *Pipes.*
- (a) *Classification.* The network of pipes should be arranged so that large primary mains feed smaller secondary pipes. Mains carry water from the source to the service pipes. Service pipes carry water from the main to the building.
 - (b) *Arrangement.* A distribution system is constructed either as a dead-end system or as a loop system. In a dead-end system a single distribution main runs from the pump or elevated storage tank to the various outlets. In a loop system the distribution main forms a single loop or a series of loops with both ends connected to the pump or elevated storage tank. The advantage of a dead-end system is the economy in length of main. The advantages of a loop system are the equal delivery capacity with smaller mains, a more uniform pressure, and the ability to make repairs with a minimum of outlets deactivated. Complete loop systems are seldom used in field installations.
 - (c) *Design and construction.* The design of a distribution system is based on the known requirements and physical data obtained from reconnaissance, surveys, and maps. TM 5-302 includes standard layouts.

88. Equipment for Purification and Treatment

a. *Standard Sets.*

- (1) The following sets are now standard:
 - (a) Water purification equipment set, trailer mounted, diatomite filter, 600 gph; primarily for airborne use.
 - (b) Water purification equipment set, truck mounted, diatomite filter, 1,500 gph; primarily for use with combat units.
 - (c) Water purification equipment set, truck mounted, diatomite filter, 3,000 gph.
 - (d) Water purification equipment set, base mounted, diatomite filter, 3,000 gph; for use as stationary equipment under Arctic conditions, and also in non-Arctic areas.
- (2) A water purification plant with a capacity of 10,000 gph is under development at ERDL, and it is expected will shortly become standard. It incorporates coagulation and rapid sand filtration apparatus.

b. Locally Designed Facilities. If standard water purification sets are not available or do not meet local requirements, other standard issue pumps are used with issue or locally designed and constructed storage and treatment facilities. The usual storage requirement is for an aggregate of half a day's supply in reservoirs and/or tanks, normally with at least one tank elevated to insure adequate head. Treatment facilities depend upon the type and quantity of water but normally include the items shown in the typical flow diagram, figure 36.

c. Typical Equipment for Storage and Treatment.

(1) *Pumps.*

(a) *Centrifugal self priming pumps.* The following are now standard:

- 10 gpm at 80 ft. head, electric driven.
- 50 gpm at 70 ft. head, electric driven.
- 50 gpm at 25 ft. head, gasoline driven.
- 115 gpm at 25 ft. head, gasoline driven.
- 166 gpm at 25 ft. head, gasoline driven.
- 200 gpm at 300 ft. head, gasoline driven.
- 500 gpm at 30 ft. head, gasoline driven.
- 1,500 gpm at 60 ft. head, gasoline driven.
- 2,100 gpm at 25 ft. head, gasoline driven.

(b) *Helical rotor type pumps.* The standard type is a deep well pump, 50 gpm at 250 ft. head, gasoline driven.

(c) *Turbine type pumps.* The standard type is a deep well pump, 200 gpm at 200 ft. head, gasoline or electric driven.

(d) *Diaphragm type pumps.* The standard type, preferred for abrasive material, delivers 200 gpm at 10 ft. head, gasoline driven.

(2) *Storage tanks.* Standard vertical cylindrical bolted steel tanks, low type, for the storage of water or petroleum products, are issued in capacities of 4,200, 10,500, 21,000, and 42,000 gallons. For the high type the standard tank has a capacity of 126,000 gallons. Standard rubber coated fabric tanks are issued in capacities of 500, 1,500, and 3,000 gallons.

(3) *Plain sedimentation tanks or basins.* (To remove sediment from raw water not coagulated.) A typical shape is shown in figure 37. To determine the size needed, assume a depth between 5 and 10 feet, plus 1 foot (6" freeboard and 6" allowance for sludge). Find the time (minutes) required for 70% of the solids to settle from a sample of the water in a bottle. Tank size is then computed from:

$$(a) \begin{array}{l} \text{Retention time} \\ \text{(minutes water} \\ \text{must stay in tank)} \end{array} = \frac{\text{Effective tank} \times \text{Settling time in}}{\text{depth (ft.)} \times \text{bottle (min.)}} \\ \text{Depth of water sample in bottle (ft.)}$$

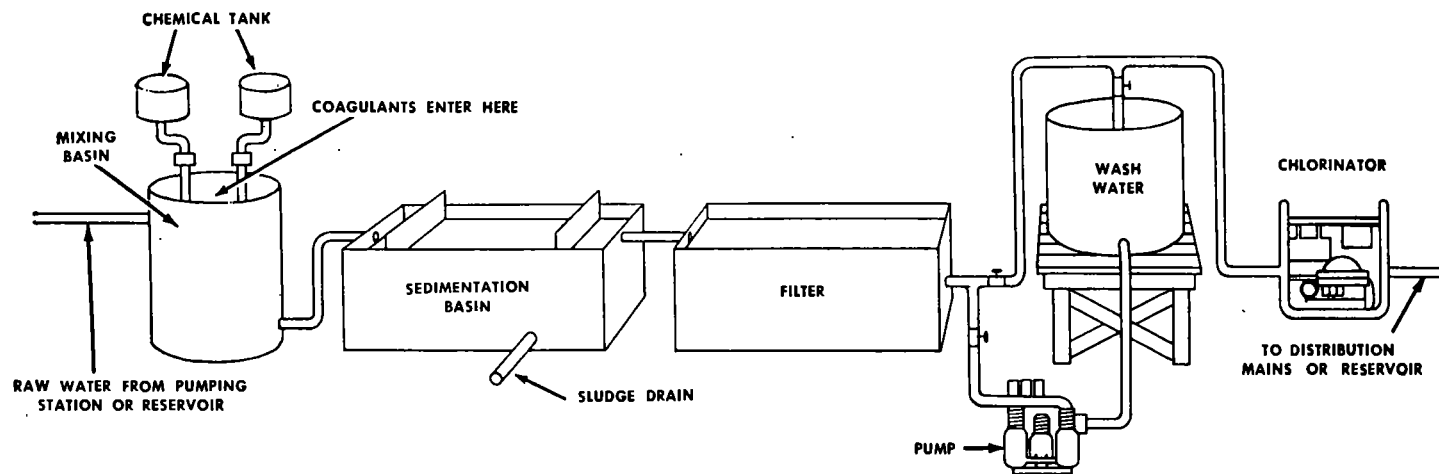


Figure 36. Flow diagram for typical water treatment plant.

$$(b) \text{ Tank capacity (cu. ft.)} = \frac{\text{Retention time (min)} \times \text{required flow (gpm)}}{7.5 \text{ (gal per cu. ft.)}}$$

$$(c) \text{ Tank length (ft.)} = \frac{\text{Retention time (min)} \times \text{velocity of flow (fpm)}}{\text{Desirable velocities are between 0.6 and 1.0 (fpm).}}$$

$$\text{Tank width (ft.)} = \frac{\text{Tank capacity (cu. ft.)}}{\text{Tank depth (effective) (ft.)} \times \text{tank length (ft.)}}$$

- (e) Example: Given: Required flow, 500 gpm; settling time in a bottle 6 inches deep, 5 min.; effective tank depth assumed at 5 feet; velocity of flow assumed at 0.9 fpm.
Solution:

$$\text{Retention time} = \frac{5 \times 5}{.5} = 50 \text{ min.}$$

$$\text{Tank capacity} = \frac{50 \times 500}{7.5} = 3,333 \text{ cu. ft.}$$

$$\text{Tank length} = 50 \times 0.9 = 45 \text{ ft.}$$

$$\text{Tank width} = \frac{3,333}{5 \times 45} = 14.8 \text{ ft. (Use 15 ft.)}$$

- (4) *Chemical-mixing and coagulation tanks.* If the water is easily coagulated, these are omitted and coagulants are added at the suction side of the pump supplying a floe sedimentation tank. If a coagulation tank is needed, its capacity should be at least 2 to 4 hours of the required flow rate; e.g., 5,000 gallons for a flow rate of 500 gpm. One type of coagulant tank with auxiliary equipment is shown as figure 38.
- (5) *Floc sedimentation tanks.* These are similar to the plain sedimentation tanks described in (3) above and the size is determined in the same way, based on the settling time for a bottle of the coagulated water as it reaches the tank. The size is usually smaller, due to more rapid settling after coagulation. A velocity of flow of 1.0 fpm is usually satisfactory.
- (6) *Filters.* For military installations too large to be served by the standard issue filters, a rapid sand filter is usually satisfactory. These filters are described as follows:
- (a) *Types and capacity.* Rapid sand filters are either gravity or pressure types, as shown in figures 39 and 40. Gravity filters are open steel tanks as shown in figure 41 or may be rectangular reinforced concrete boxes, operated as shown in figure 41. Pressure filters are inclosed vessels in which water is pumped through the bed of filter sand. Gravity filters are best for large installations; pressure

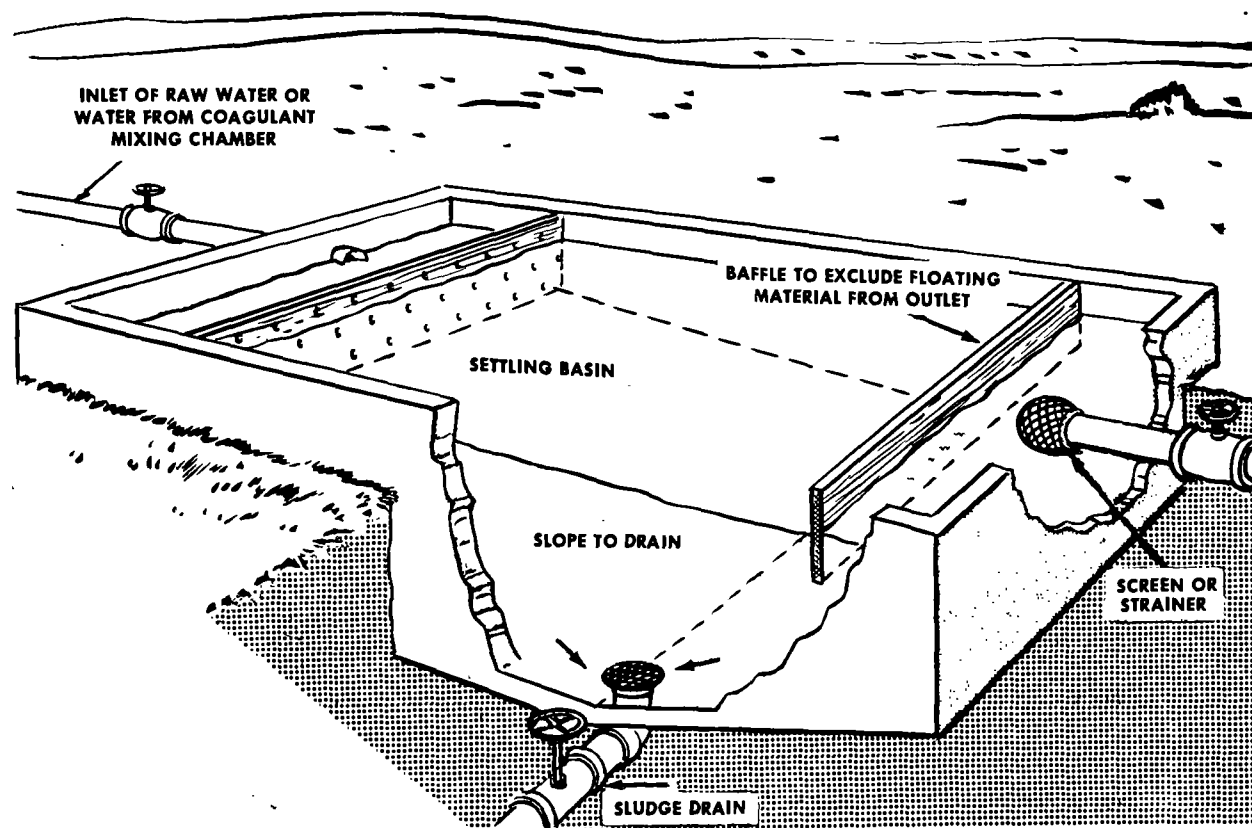


Figure 37. Settling tank for either plain or coagulated sedimentation.

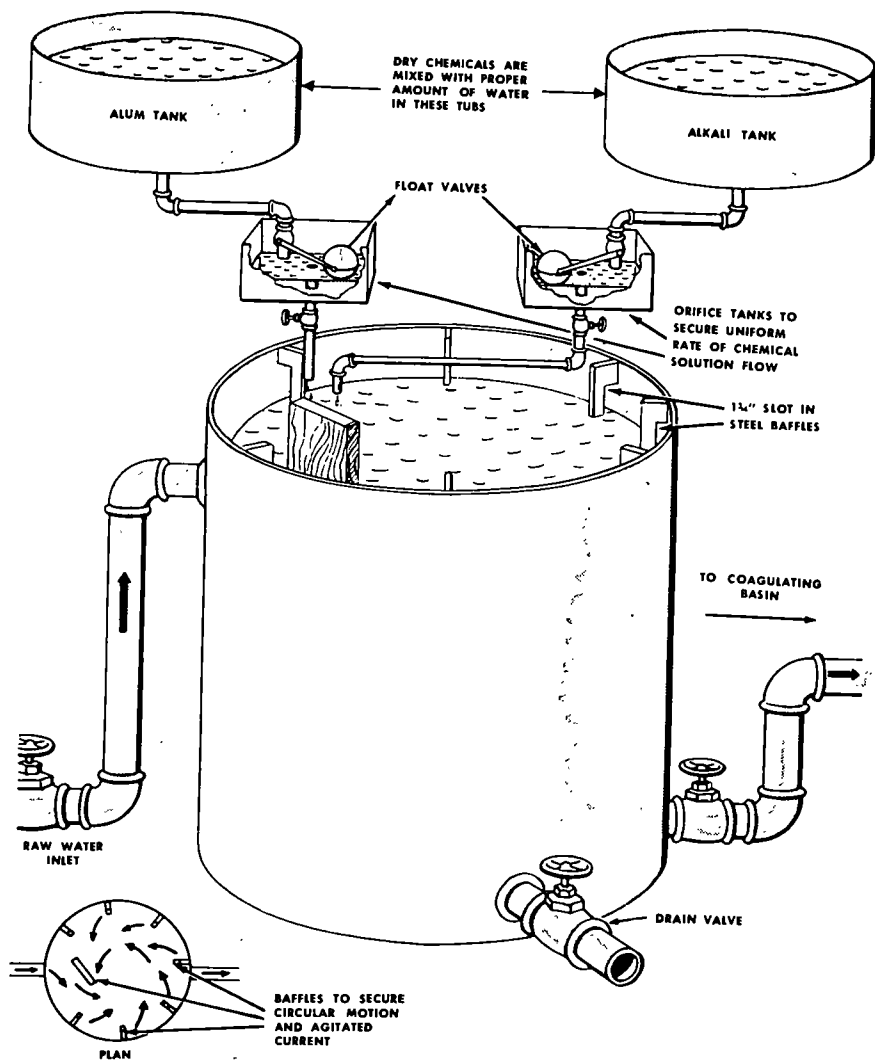


Figure 38. Coagulation tank and chemical mixing tanks.

filters are preferable for filtering small volumes of water because only one pump is required and all valves are accessible. The capacity of each type is usually 2 to 3 gpm per square foot of filter bed.

(b) *Filter media.*

1. Filter sand must be free from clay, loam, lime and organic matter, and with uniform grains of the proper size. For rapid sand filters, the preferred sands as to grain sizes are those which have an effective grain size between 0.40- and 0.60-mm, and a uniformity coefficient lower

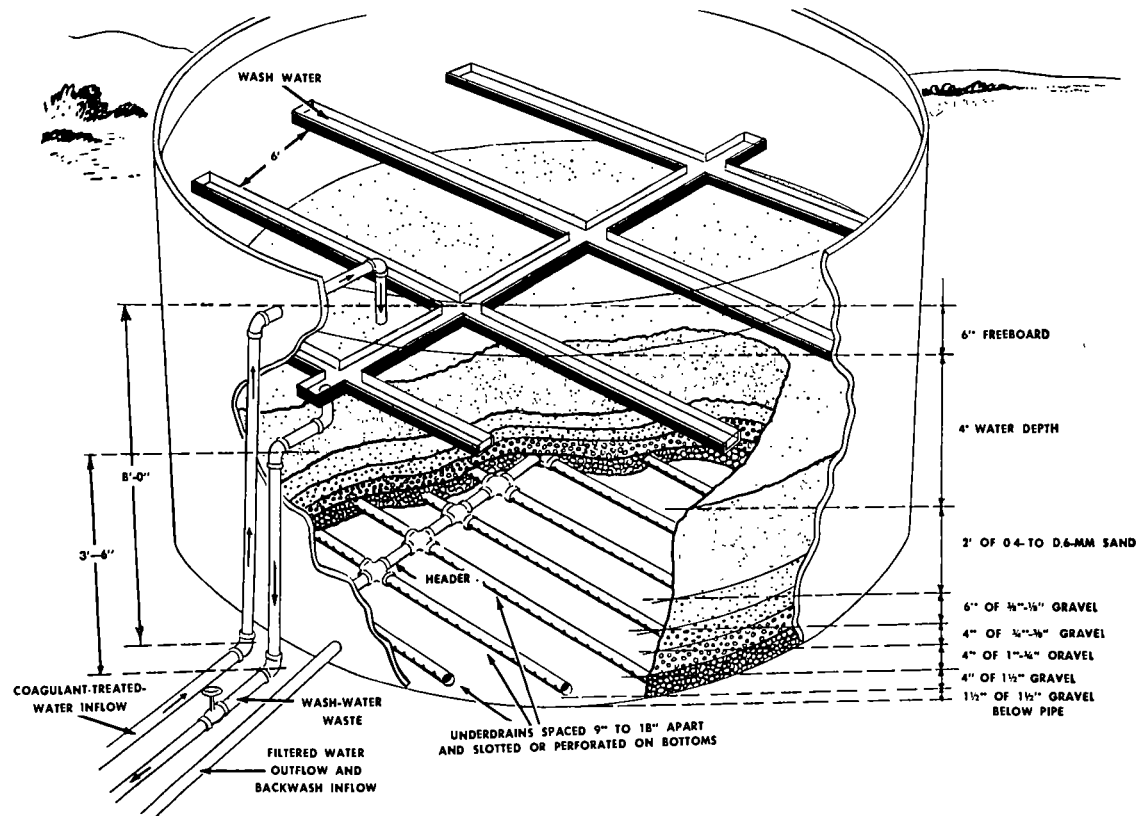


Figure 39. Typical gravity filter, showing relationship of filter medium, gravel, and underdrain.

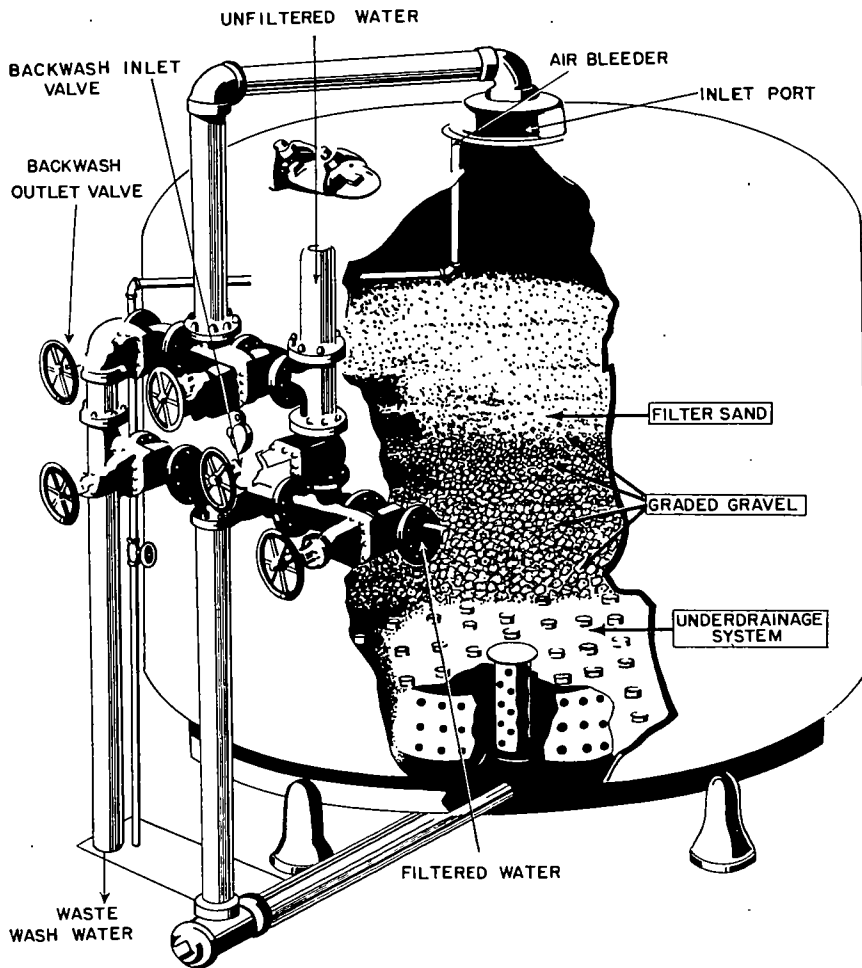
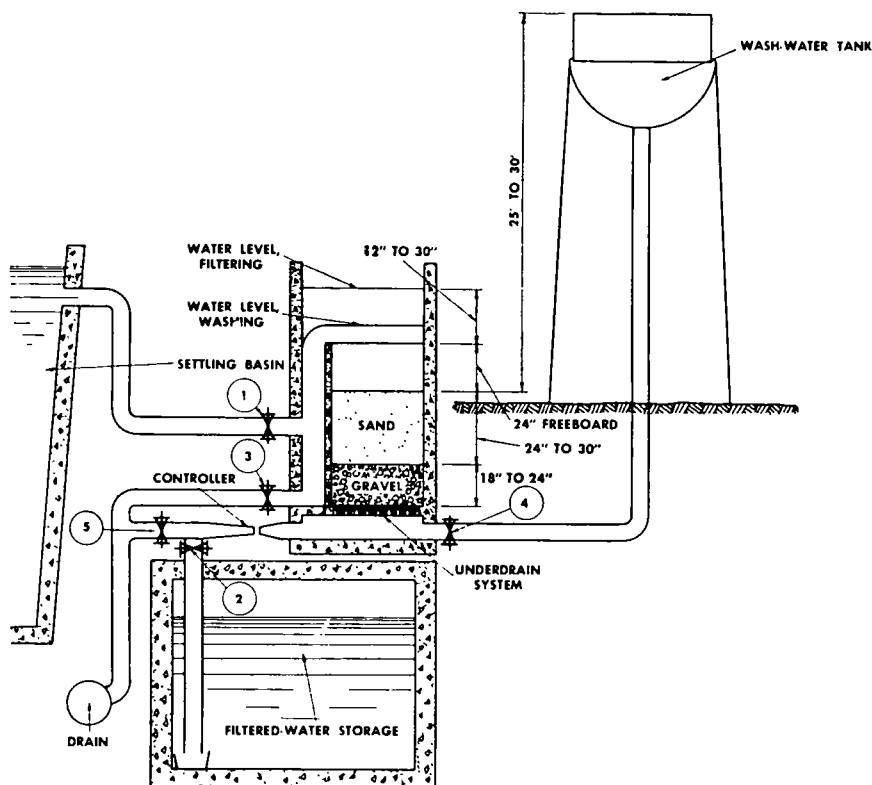


Figure 40. Pressure-type rapid sand filter.

than 1.75. Effective grain size is that grain size in a given sample which is larger than 10 percent of, but smaller than 90 percent of, the grains in the sample. The uniformity coefficient is the grain size such that 60 percent of the grains are smaller, divided by the effective size. Thus if 60 percent of a sample passes a sieve with 0.42-mm openings and 10 percent passes a sieve with 0.15-mm openings, the uniformity coefficient is $0.42 \div 0.15$, or 2.8.

2. Anthrafilt, a product made from freshly mined anthracite coal, is an acceptable substitute.



NOTE:

To operate filter, open valves 1 and 2. To backwash, close valve 1; after water already in filter flows down to top of wash-water trough, close valve 2 and open valves 3 and 4. To run water from filter to waste, close valves 2, 3 and 4 open valves 1 and 5.

Figure 41. Operating a gravity-type rapid sand filter.

3. Filter gravel, composed of hard, durable pebbles, is usually placed in graded layers, coarsest at the bottom, as follows:

Layer No.	Passing screen opening (inches)	Retained on screen opening (inches)	Depth of layer (inches)
1-----	2½	1½	4
2-----	1½	¾	6
3-----	¾	½	4
4-----	½	¼	4
5-----	¼	⅛	4

(c) Typical operating criteria.

1. Washing is needed when the loss-of-head gage, figure 42, shows a loss of 7 to 9 feet or after a filter run of 100 hours. (Sudden decrease in loss-of-head usually means cracks in the filter bed surface. These require prompt correction or a backwash, to insure satisfactory filtering.)

2. Best wash-water velocity is between 15 and 20 gpm per square foot of filter surface. This is equivalent to a rise in water level of between 2 feet and 2.5 feet 4 inches per minute, with valve 4 (figure 41) in operating position. Normally the desirable velocity is the highest velocity which is attainable without loss of filter sand.

(7) *Hypochlorinators.*

- (a) The standard portable pumping and hypochlorinator unit, 50 gpm, pumps water from a source, applies a hypochlorite solution, and delivers 50 gpm of chlorinated water against a head of 50 feet, of which 15 feet may be suction. It is useful for small installations.
- (b) The standard portable automatic hypochlorinator, 2 to 100 gpm, when installed on a bypass connection assembly on a 4-, 6-, or 8-inch main, chlorinates flows ranging from 2 to 400 gpm.

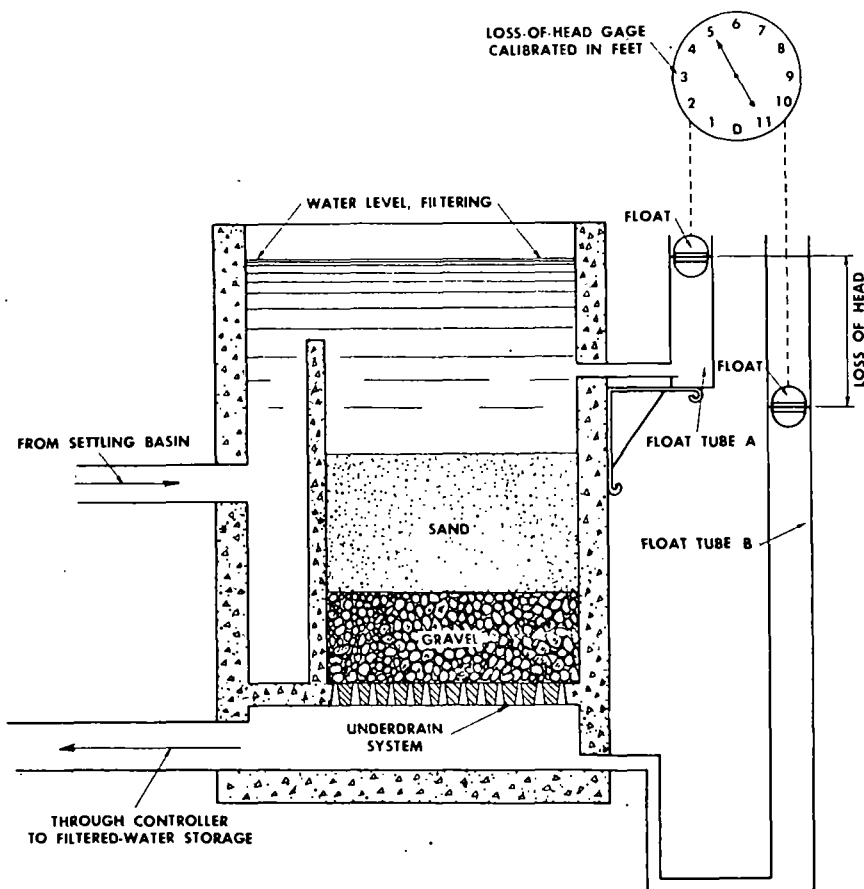


Figure 42. Loss-of-head measurement.

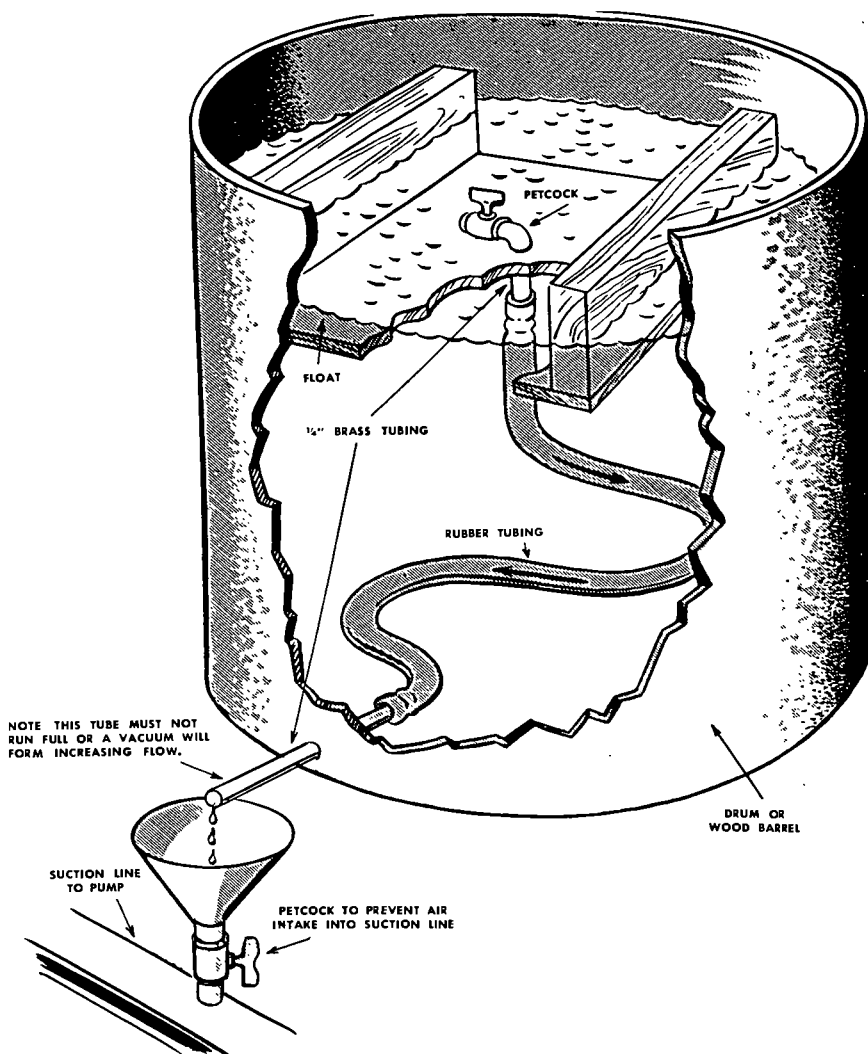


Figure 43. Improvised constant-flow chlorinating apparatus.

- (c) Commercial type chlorinators may be available in existing installations. These usually require the use of liquid chlorine in cylinders.
- (d) If neither standard nor commercial chlorinators are available, constant-flow apparatus is improvised as shown in figure 43, and controlled manually.

89. Expedient Distillation

a. When necessary, expedient stills are built to produce potable water from a source of heat, a method of forming and collecting steam, and some kind of condenser. The efficiency of an expedient still

depends on the materials available and the ingenuity of the designer. In expedient distillation, sufficient vapor-separating space is provided to prevent carryover of salt with the steam. Care is taken to avoid getting salt in the distillate through the expedient means used to condense the steam. To avoid endangering personnel by the building up of excessive steam pressure, never put a valve in the distillate line.

b. Figure 44 illustrates an expedient still with water-cooled condenser.

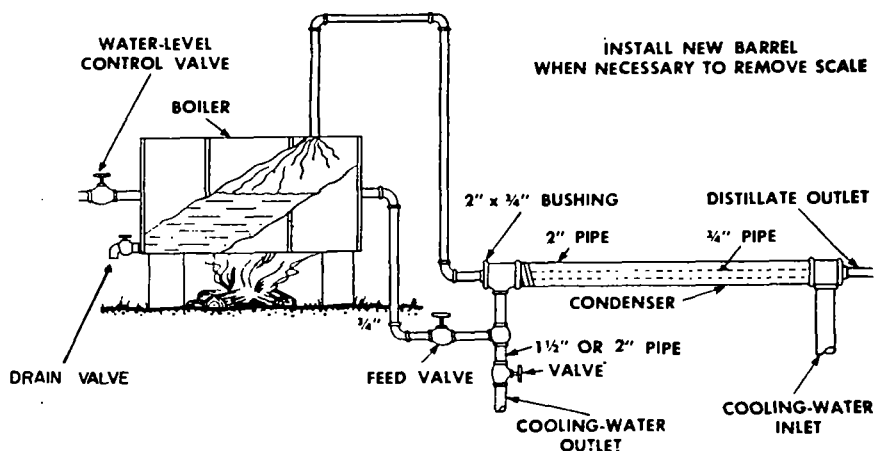


Figure 44. Expedient still, water-cooled condenser.

90. Hypochlorination Units

See table 80.

91. Water Demands

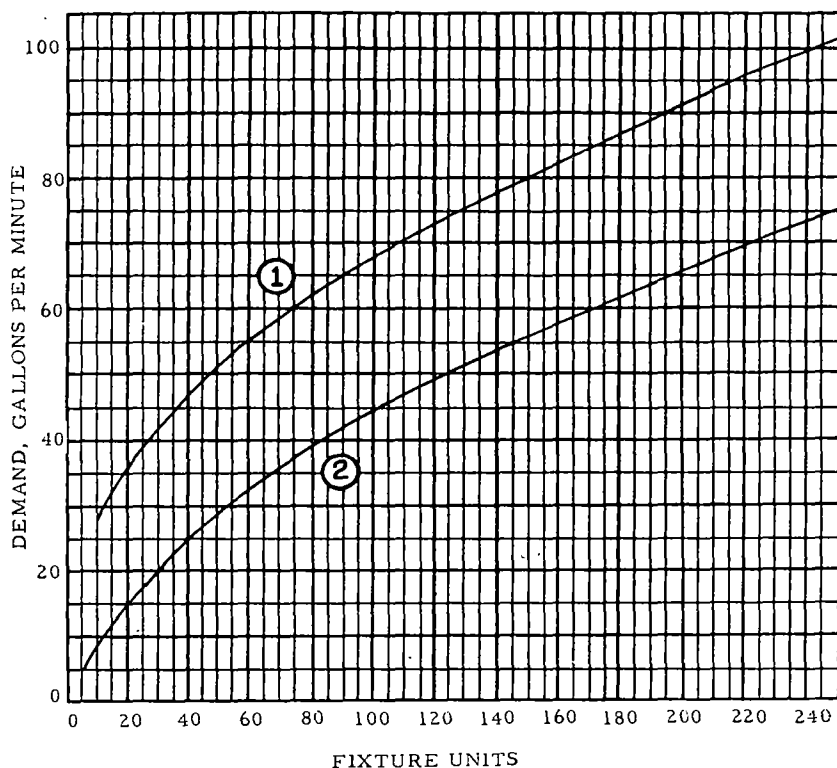
a. *General.* Delivery of water through a distribution system is continuous and in sufficient quantity to meet the maximum rate of demand (peak demand).

b. *Peak Demand for a System.* The size of a water main serving an area depends on the total peak demand for that area. Service connections and mains are made large enough to deliver the total peak demand under the available pressure. Figures 45 and 46 give the peak demand, in gallons per minute, in terms of the number of fixture units on a main. Figure 45 (1) is for a system with 240 fixture units or less; figure 45 (2), for a system with more than 240.

c. *Fire-Protection Demand.* In temporary installations it may be impracticable to construct distribution systems large enough to meet the demand of firefighting equipment. In such cases it is best to provide ground storage tanks or sumps, so located that any building can be reached with not over 1,000 feet of hose. Water is pumped by fire pumper trucks or skid-mounted pumps.

Table 80. Hypochlorination Units

Unit	Operation	Capabilities	Length, Width, Height, Weight	Remarks
Hypochlorination unit, automatic, portable.	Water-pressure operated. Virtually automatic, requiring only 1 operator under all conditions.	Installed in 2'' pipe or hose, it chlorinates water pumped at rates from 2 to 100 gpm. Installed on a bypass from 4- or 6-inch main, it chlorinates flows from 2 to 400 gpm. When set for maximum flows expected, the unit proportions the solution for flows down to one-tenth the maximum.	L=25'' W=18½'' H=26'' Wt=165#	For planning purposes, the chemical requirement is 1 ounce of calcium hypochlorite (70% available chlorine) per 1000 gallons. See TM 5-2032 for details of operation. Requires a minimum continuous water pressure of 10 psi; 5 psi of which is lost to friction. There is a constant small wastage of water from the unit.
Pumping and hypochlorination unit, portable.	Gasoline engine coupled to a centrifugal pump with a belt-driven hypochlorinator.	This unit pumps and treats water which requires chlorination only. It delivers 55 gpm of chlorinated water against a total head of 50 feet, 15 feet of which may be suction.	L=31'' W=25'' H=38'' Wt=285#	See TM 5-295 for details of operation.



CURVE NO. 1 FOR SYSTEM WITH FLUSH VALVES
CURVE NO. 2 FOR SYSTEM WITH FLUSH TANKS

Figure 45 (1). Supply-demand curve, for fixtures not exceeding 240.

92. Water Pressures

a. Supply Mains and Pumps. Working pressures for the supply mains vary with the equipment available. The pumps and equipment described in TM 5-350 are designed for maximum pumping pressures of 200 to 400 pounds to the square inch. High pump pressure permits the use of smaller pipe without reducing the supply-main capacity. However, pressure must be multiplied by about 4 to double the capacity of a main, whereas doubling the cross-sectional area of the main accomplishes about the same result. It is materially more economical to operate and maintain pumps and pipes at 100 to 150 pounds to the square inch than at higher pressures.

b. Distribution. Pressures in distribution mains are held down—by pressure-reducing valves, if necessary—to avoid exceeding the allowable pressure at outlets. This allowable pressure is established to minimize faucet leakage, wear and tear on faucets and fixtures, and water-hammer damage. It is usually set at between 20 and 75 pounds to the square inch and as near 20 pounds to the square inch as will

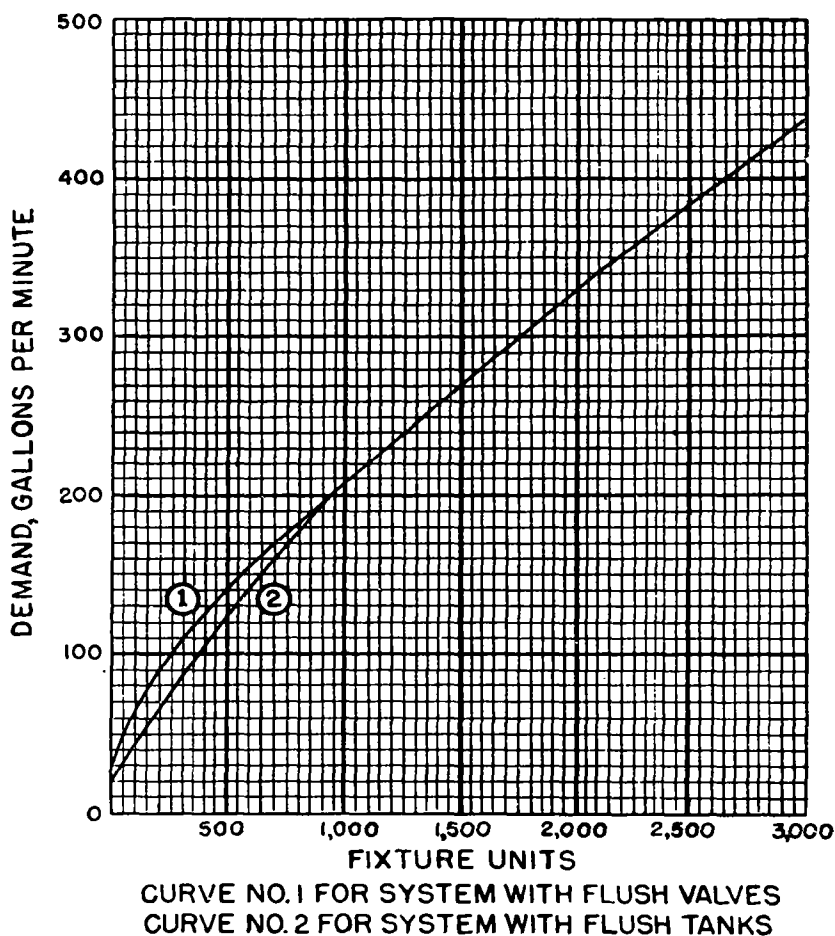


Figure 45 (2). Supply-demand curve, for fixtures in excess of 240 units.

prevent outlet pressures from falling below 20 pounds to the square inch at a time of peak demand. A valved bypass around the reducing valve permits any temporary pressure increase needed for firefighting.

c. *Characteristics of Pipes.* Table 81 gives dimensions, weights, and other data of standard steel and other pipes in ordinary use. See also table 155. For friction losses, see paragraph 93. For comparative discharge capacities, see paragraph 95.

93. Friction Losses

Friction losses in service connections and distribution mains are normally based on the use of iron or steel pipe, using the $C=120$ in the Hazen and Williams formula for temporary camps, and $C=100$ for permanent camps. The alinement charts in figures 46 and 47 are used for computing friction losses in straight pipes and in valves and fittings.

Table 81. Properties of Pipeline Materials

Item	Normal sizes		Physical properties											
	Length (ft.)	Diameter (in.)	Friction ¹ coeff. C	Working press (psi)	Weight per lin. ft. (lb.)									
					¾	2	4	6	8	12	18	24	36	48
Cast iron.....	12.....	4 to 84.....	140 (new) to 100 (old).	Class A, 50..... Class B, 100..... Class C, 150..... Class D, 200.....	.....	.....	19.2 19.2 19.2 19.2	30.0 30.0 30.0 30.0	42.9 42.9 42.9 42.9	73.3 73.3 77.9 83.8	.....	.....	.....	.....
Steel, A.P.I.....	20.....	4, 6, 8.....	140.....	1,400 (4")..... 1,300 (6")..... 950 (8").....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Steel, pipeline tubing.....	20.....	4, 6.....	140.....	650.....	.....	.....	4.8	10.9	16.2	.....	.....	.....	.....	.....
Steel, seamless or weld.....	20.....	¾, 1½, 2.....	140.....	Std.....	1.1	3.7	10.9	19.2	28.8	50.7	.....	.....	.....	.....
		4, 6, 8.....	.....	Extrastrong.....	1.5	5.0	15.0	28.6	43.4	65.4	.....	.....	.....	.....
Wrought iron.....	20.....	¾, 2, 4, 6, 8.....	130 to 140.....	Std.....	1.1	3.7	10.9	19.2	28.8	50.7	.....	.....	.....	.....
				Extrastrong.....	1.5	5.0	15.0	28.6	43.4	65.4	.....	.....	.....	.....
Wood, bonded.....	6-16.....	4, 6, 8, 12.....	120.....	45.....	.....	.....	5.8	8.7	11.2	17.7	28.8	41.4	.....	.....
Bituminized fiber.....	8 (4"), 5 (6"), 8".....	4, 6, 8.....	150.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Asbestos cement (transite).....	10.....	2 to 3½.....	140.....	50.....	.....	.....	4.7	7.6	11.7	19.8	35.9	55.5	126	.....
	13.....	4, 6, 10, 12.....	.....	100.....	.....	.....	5.0	7.8	11.9	27.6	58.2	99.3	211	.....
	.....	14, 16, 18, 20.....	.....	150.....	.....	.....	6.0	10.7	16.8	38.6	81.2	141	318	.....
	.....	24, 30, 36.....	.....	200.....	.....	.....	8.4	15.4	23.7	49.6	112	199	435	.....
														
Concrete, sewer.....	2, 2.5, 3, 4.....	4 to 24.....	130 to 140.....	.....	.....	.....	.....	25	35	60	120	225	.....	.....
Concrete sewer, reinforced.....	1.....	12 to 100.....	130 to 140.....	.....	.....	.....	.....	.....	.....	100	160	260	450	720
Concrete culvert, reinforced.....	3.....	12 to 100.....	130 to 140.....	.....	.....	.....	.....	.....	.....	100	160	320	520	850
Concrete culvert, extrastrong.....	3.....	24 to 100.....	130 to 140.....	.....	.....	.....	.....	.....	.....	.....	.....	320	520	850
Clay, sewer.....	2, 2.5, 3.....	4 to 36.....	110.....	.....	.....	.....	8.0	14.5	23.0	43.5	96.0	172	370	.....
Clay, culvert.....	2, 3.....	6 to 36.....	.....	.....	.....	.....	.....	15.5	24.0	55.5	116	218	505	.....
Corr. metal:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16 ga.....	2.....	8 to 84.....	Less than 100.....	.....	.....	.....	.....	.....	7.6	10.8	15.8	21.0	.....	.....
14 ga.....	.....	.....	.....	.....	.....	.....	.....	.....	9.3	13.3	19.5	26.0	37.9	50.5
12 ga.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.5	27.0	35.9	52.4	70.0

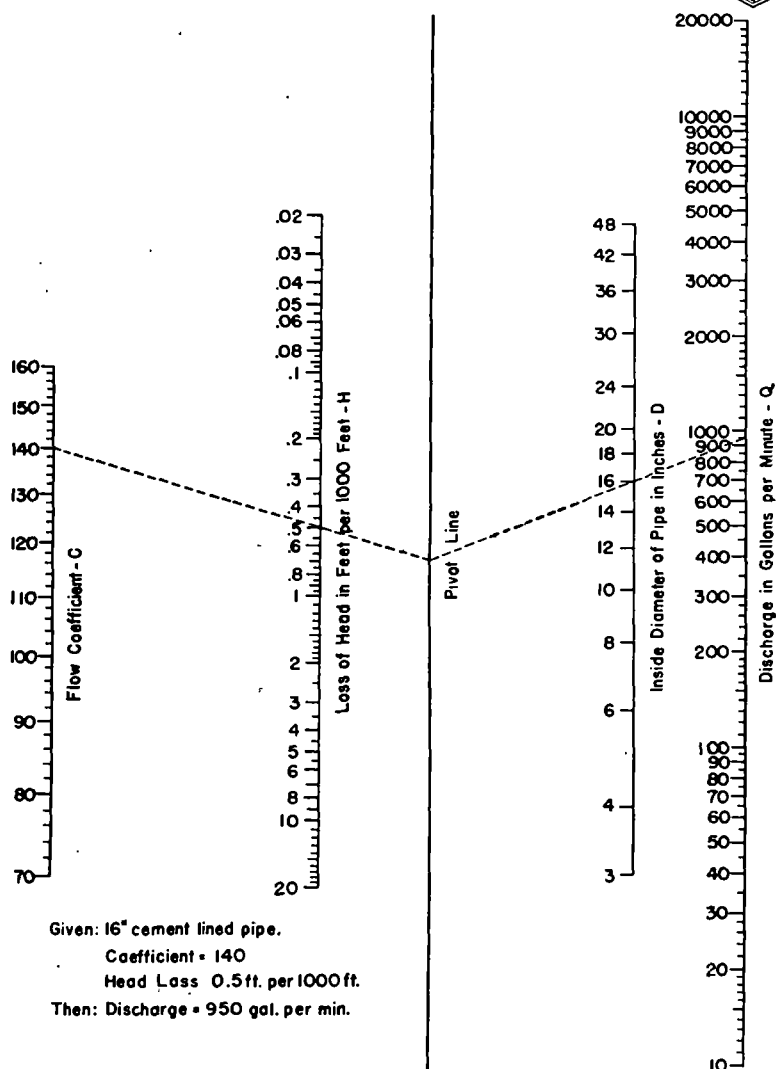
See footnotes at end of table.

Table 81. Properties of Pipeline Materials—Continued

Item	Physical properties—Continued													Remarks
	Three-edge bearing strength (lb. per ft.)													
	4	6	8	10	12	15	16	21	24	30	36	42	48	
Cast iron.....														Moderately corrosion-resistant, brittle. (0.013).
Steel, API.....														Moderately corrosion-resistant. (0.012).
Steel pipeline tubing.....														Mildly corrosion-resistant, semiflexible.
Steel, seamless or weld.....														
Wrought iron.....														Corrosion-resistant ductile. (0.011).
Wood, bonded.....														Noncorrosive.
Bituminized fiber.....														Noncorrosive, semiflexible, also perforated in 4" size. (0.010).
Asbestos cement (Transite).....	1,740	1,420		2,580 3,690 4,920	2,370 3,850 5,100		2,030 4,140 5,360 6,340		2,340 4,650 7,050 8,600	2,980 3,000 6,180 10,450	3,500 5,400 9,700 12,300			Noncorrosive, lightweight, brittle. (0.012).
Concrete, sewer.....	1,000	1,100	1,300	1,400	1,500	1,750	2,000	2,200	2,400					Noncorrosive, brittle. (0.010–0.015).
Concrete sewer, reinforced.....					1,800	2,030	2,200	2,400	2,400	2,700	3,000	3,200	3,400	Noncorrosive, brittle.
Concrete culvert reinforced.....					2,250	2,625	3,000	3,000	3,000	3,375	4,050	4,725	5,400	Noncorrosive, brittle.
Concrete culvert extrastrong.....									4,000	5,000	6,000	7,000	8,000	Noncorrosive, brittle.
Clay, sewer.....	1,000	1,000	1,000	1,100	1,200	1,400	1,700	2,000	2,400	3,200	3,900			Noncorrosive, brittle, imperv. (0.015–0.013).
Clay, culvert.....		2,000	2,000	2,000	2,250	2,750	3,300	3,830	4,400	5,000	6,000			Noncorrosive, brittle, imperv.
Corr. metal:														
16 ga.....														Semiflexible. (0.021) (0.017–0.019) coated.
14 ga.....														
12 ga.....														

¹ Hazen Williams.

Note. Weights of concrete and corrugated metal pipe in 15", 21", 30", and 42" sizes may be interpolated from data shown. Weights or strengths of asbestos-cement pipe in 10", 14", 16", 20", and 30" sizes also may be estimated by interpolation.



NOMOGRAM FOR CALCULATING PIPE SIZE, DISCHARGE AND HEAD LOSS

The above nomogram is based on the Williams-Hazen formula: $Q = .006756 CD^{2.63} H^{.54}$. The coefficient of cement-lined Mono-Cast pipe is 140.

Figure 46. Alinement Chart for calculating pipe size, discharge, and head loss.

EXAMPLE: DOTTED LINE SHOWS THAT RESISTANCE OF A 6" STANDARD SHORT RADIUS ELBOW IS EQUIVALENT TO 16' OF 6" STANDARD PIPE.

NOTE: FOR SUDDEN ENLARGEMENTS OR CONTRACTIONS, USE THE SMALLER DIAMETER, *d*, ON PIPE SIZE SCALE.

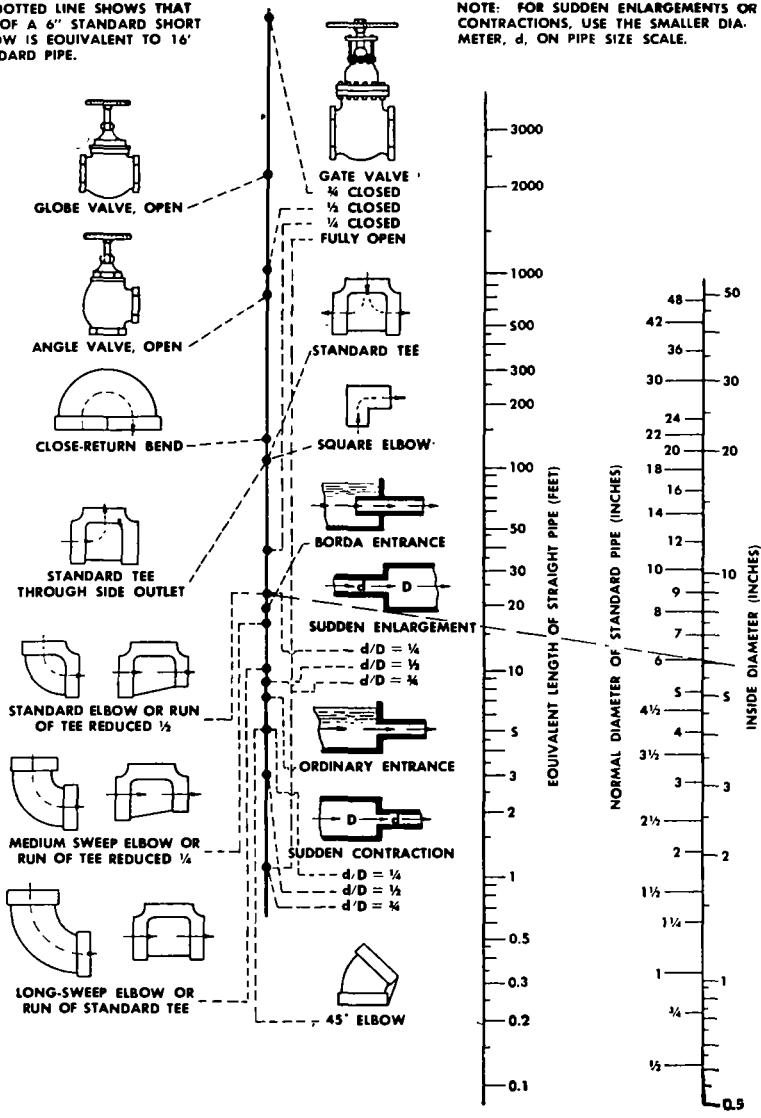


Figure 47. Friction chart for valves and fittings.

94. Fixtures

Table 82. Schedule of Fixtures per Branch

Size of branch (inches)	Connections allowed	
	Size (inches)	Number
3/8-----	3/8	1
1/2-----	3/8	5
1/2-----	1/2	3
3/4-----	1/2	8
1-----	1/2	15
1 1/4-----	1/2	27
1 1/2-----	1/2	42

Table 83. Recommended Pipe Sizes for Fixture Branches

Fixture	Fixture branch size (inches)
Lavatory-----	3/8 for hot and cold.
Bathtub-----	1/2 for hot and cold.
Kitchen sink, small-----	1/2 for hot and cold.
Kitchen sink, large scullery-----	3/4 for hot and cold.
Laundry trays-----	1/2 for hot and cold.
Shower stall per head-----	1/2 for hot and cold.
Water closets, flush-tank-----	3/8 cold.
Water closets, flush-valve-----	1 cold.
Pedestal urinals, flush-valve-----	1 cold.
Wall type urinals, flush-valve-----	1/2 cold.

Table 84. Rates of Flow Through Fixtures ¹

Fixture	Gallons per minute									
	1	2	3	4	6	8	10	15	20	25
Number of Fixtures-----										
Water closets with tanks-----	5	10	12	15	23	26	40	50	66	75
Urinals with tanks-----	4	8	10	12	20	23	34	48	58	65
Water closets, flush-valve-----	27	45	55	70	95	115	135	150	170	200
Urinals, flush-valve-----	15	25	33	45	58	75	82	88	94	100
Lavatories (based on 1 faucet)-----	3	5	8	10	15	18	24	33	40	48
Bathtub (based on 1 faucet)-----	10	18	26	32	45	56	66	90	120	150
Shower head, watersaver-----	4	8	12	16	20	24	30	45	55	70
Shower head, rain type-----	8	16	24	32	42	56	70	95	120	150
Kitchen sink, small (per faucet)-----	6	10	14	16	24	32	40	54	70	85
Kitchen sink, large (per faucet)-----	8	14	18	24	32	40	50	63	91	103
Service sink (per faucet)-----	10	18	24	28	36	44	52	68	88	110
Laundry tray (per faucet)-----	8	14	18	24	32	40	50	63	81	103
Drinking fountains-----	2	3	4	5	6	7	8	10	12	15
Hose bibbs, 1/2 inch-----	5	8	11	14	25	34	40	60	80	100

¹ Calculated at 40 psi.

95. Comparative Discharge Capacities of Water Pipes

Table 85. Comparative Discharge Capacities of Water Pipes

Size of pipe (inches)	Number of equivalent pipes								
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
$\frac{3}{8}$ -----	1								
$\frac{1}{2}$ -----	1.8	1							
$\frac{3}{4}$ -----	3.6	2	1						
1-----	6.6	3.7	1.8	1					
$1\frac{1}{4}$ -----	13	7	3.6	2	1				
$1\frac{1}{2}$ -----	19	11	5.3	2.9	1.5	1			
2-----	36	20	10	5.5	2.7	1.9	1		
$2\frac{1}{2}$ -----	56	31	16	8	4.3	2.9	2	1	
3-----	97	54	27	15	7	5	2.8	1.8	1

Note. To find number of smaller pipes equal to a larger size, read down from smaller pipe size, across from larger size; read answer at intersection. Thus, capacity of one $2\frac{1}{2}$ -inch pipe equals capacity of eight 1-inch pipes.

Section II. SEWERAGE

96. General

The subject of sewerage is dealt with in a general way in TM 5-302 and TM 5-283. Further details are given in TM 5-665 and TM 5-666. Sanitary aspects of the problem are discussed in FM 21-10.

97. Quantities of Sewage

The quantity of sewage that is disposed of varies with the number of personnel served and the restrictions placed on the use of water. Flows generally range between 15 and 50 gallons per capita per day, although permanent installations with ample water supplies may use more. The average flow from temporary installations is about 25 gallons per capita per day, and this is increased by 50 gallons for each bed in hospitals. The peak rate of flow for short periods in the day may be three times the average rate. The curve in figure 48 shows the ratio of peak flow to average flow.

98. Stream Flow Required For Dilution

The amount of stream flow required for disposal by dilution depends on the strength and quantity of the sewage, the density and nearness of the population to the stream bank, and the industrial or domestic use of the stream water below the outfall. A stream overloaded with sewage develops sludge banks and surface scum, is unsightly, and emits an offensive odor. For streams not used for industrial and domestic water supply below the sewage outfall, table 86 provides a guide in determining the quantity of sewage that may be discharged. This table gives the minimum stream flow required for dilution of raw and treated sewage. If enough water is not

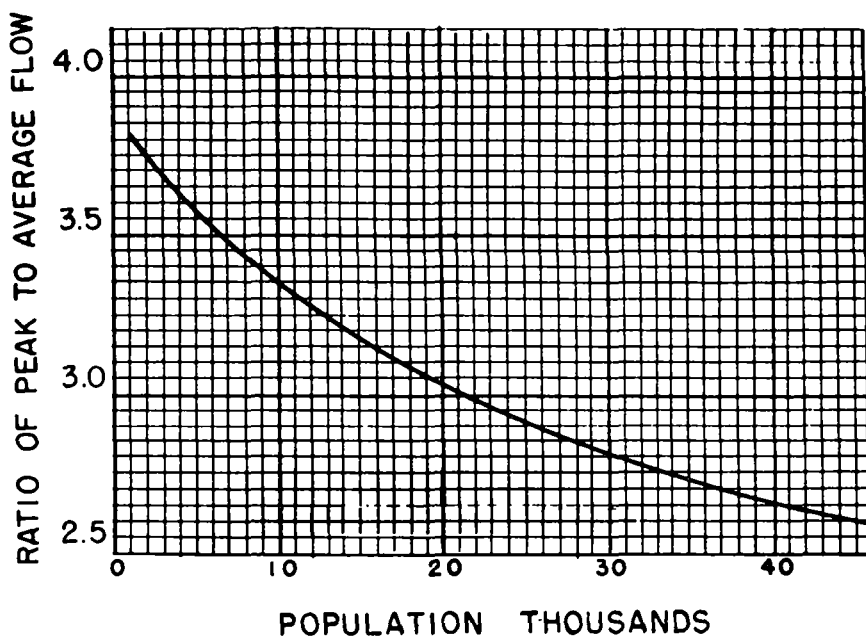


Figure 48. Ratio of peak to average sewage flow.

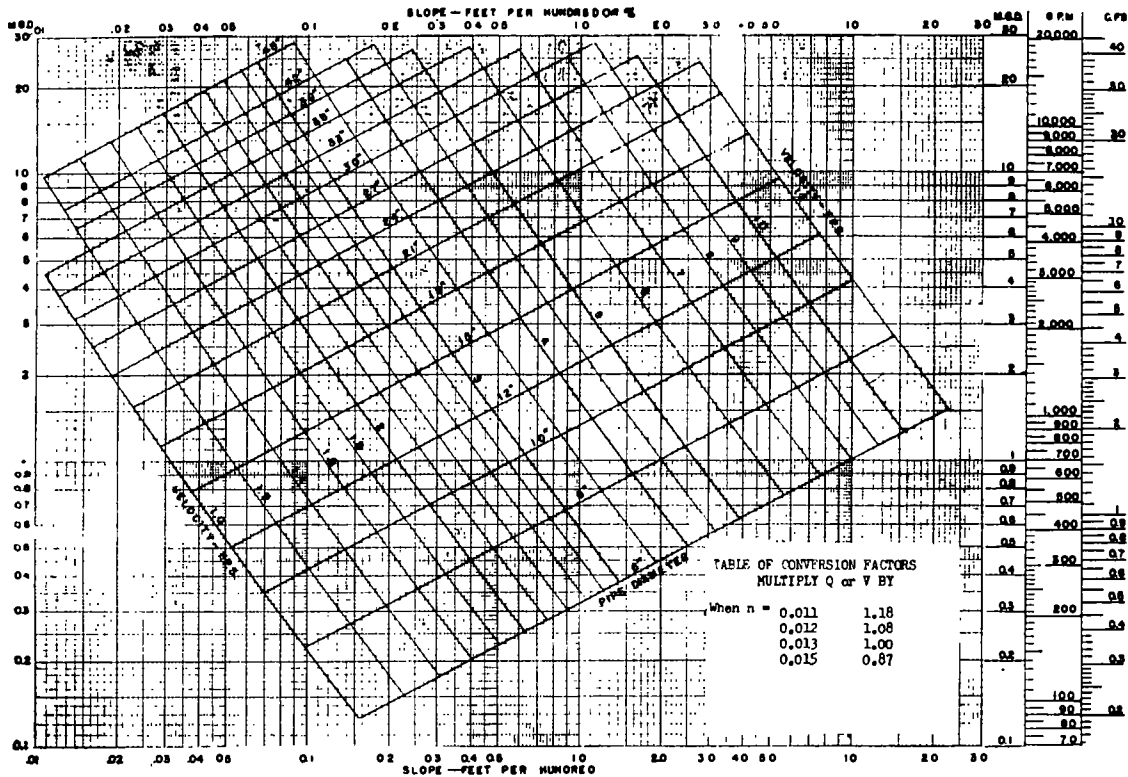
available for dilution, oxidation ponds, leaching cesspools, or tile distribution fields are used for disposal of surplus sewage, taking adequate precautions to avoid contamination of the water supply.

Table 86. Minimum Stream Flow Required for Dilution

Type of treatment	Dilution per 1,000 sewage-contributing population	
	Densely populated areas	Sparsely populated areas
None.....	20 c.f.s. and over.....	5 c.f.s. and over.
Partial (settling).....	12 to 20 c.f.s.....	3 to 5 c.f.s.
Complete.....	6 to 12 c.f.s.....	0 to 3 c.f.s.

99. Sanitary Sewers

a. Layout. To avoid deep excavations sewers are located along natural drainage lines. If possible, they are not laid longitudinally under roadways. Road crossings are kept to a minimum and where less than 4 feet of cover is available the pipe is reinforced by back-filling the lower 2 feet of the trench with low-grade concrete. In light traffic areas, sewers should be covered with at least 2 feet of well-compacted earth. Connections adjoining buildings may need only 1 foot of cover. Manholes are located at each change of direction, size, or slope and usually are placed at the end of each lateral. On



PIPE FLOW CHART KUTTER'S FORMULA (N = 0.13)

Figure 49 (1). Pipe flow diagram.

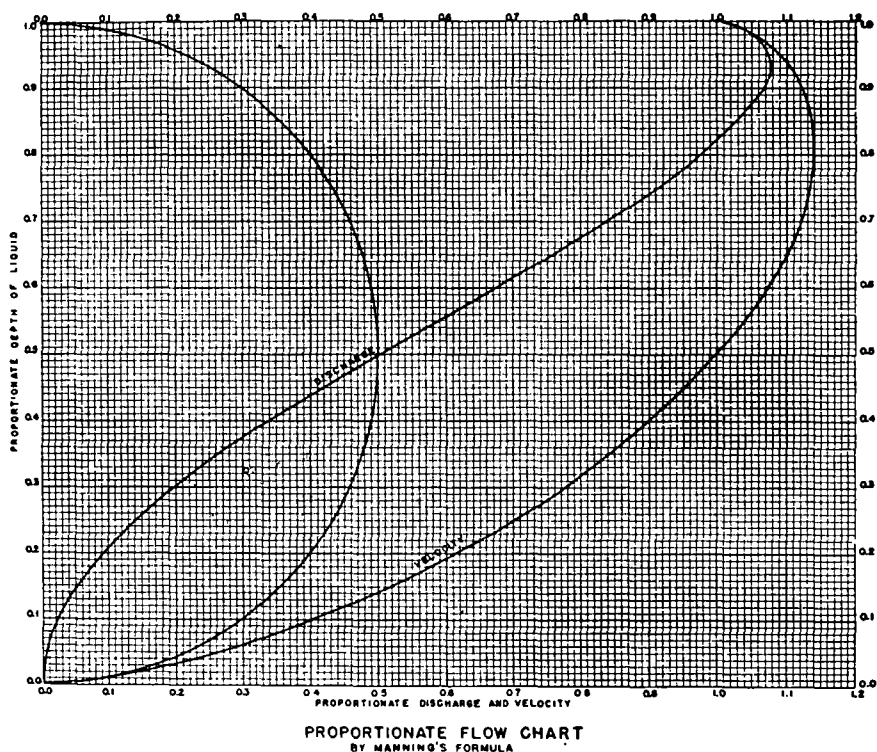


Figure 49 (2). Proportionate flow chart.

straight sections of sewers, the maximum distance between manholes is 400 feet. Two hundred to three hundred feet spacing is preferable.

b. Size. The size of sewer required to carry a given capacity depends on the slope of the sewer and the resistance to flow caused by the interior surface of the pipe. Pipes less than 4 inches in diameter (on a slope of $\frac{1}{8}$ -inch per foot) are not used, because they clog and require frequent cleaning. Four-inch pipe may be used on house sewers; lateral sewers are 6 inches or more in diameter.

c. Velocity. To prevent the settling out of solids the minimum velocity is 2 feet per second when the sewage flow is at the full capacity of the sewer. However, in unfavorable terrain a velocity of 1.5 fps is satisfactory.

100. Sizes of Sewer Lines

a. Table 87 is based on an assumed peak load of 75 gallons per capita per day. (This is for permanent installations; in a theater of operations, use 25 gallons per day.) Flow is from Kutter's formula, using $n=0.013$. For further information see pipe flow diagram (figure 49 (1)) and proportionate flow chart (fig. 49 (2)).

b. The following examples illustrate the use of the pipe flow diagram and the proportionate flow chart as shown in figures 49 (1) and 49 (2).

(1) To determine pipe size:

Assume a peak sewage flow of 150 GPM on a 1% slope. Using Figure 49 (1) find intersection of horizontal line from 150 GPM and vertical line of 1%. This falls below a 6" Pipe—the 6" must be used on a trial basis. Then using a 6" pipe on a 1% slope the flow conditions for *FULL FLOW* can be found; i.e., 230 GPM capacity and 2.5 fps velocity. To find what the actual flow conditions would be, Figure 49 (2) must be used.

(2) To use Proportionate flow chart 49 (2) the Proportionate discharge must be found by:

$$\frac{Q_{\text{ACTUAL}}}{Q_{\text{FULL FLOW}}} = \frac{QA}{Q_c} = \frac{150}{230} = 0.65$$

By entering proportionate flow chart at 0.65 construct perpendicular line to discharge curve then horizontal to velocity thence straight down and read proportional velocity $\frac{V_A}{V_c}$ is 1.06—the actual velocity at 150 GPM will be 1.06×2.5 or 2.7 fps.

Table 87. Sizes of Sewer Lines

Pipe diameter (inches)	2-f.p.s. velocity			1.5-f.p.s. velocity		
	Slope (ft. per 100 ft.)	Discharge (g.p.m.)	Population capacity	Slope (ft. per 100 ft.)	Discharge (g.p.m.)	Population capacity
6-----	0. 63	176	3, 300	0. 36	132	2, 500
8-----	. 40	314	6, 000	. 23	235	4, 500
10-----	. 28	490	9, 000	. 16	368	7, 000
12-----	. 21	707	13, 000	. 12	530	10, 000
14 ¹ -----	. 17	960	18, 000	. 095	721	13, 000
15-----	. 15	1, 104	21, 000	. 086	828	15, 000
16 ¹ -----	. 14	1, 260	24, 000	. 078	942	18, 000
18-----	. 12	1, 590	30, 000	. 067	1, 192	22, 000
20 ¹ -----	. 10	1, 970	37, 000	. 056	1, 472	28, 000
21-----	. 09	2, 160	41, 000	. 053	1, 623	31, 000
24-----	. 076	2, 825	54, 000	. 044	2, 120	40, 000

¹ These sizes are nonstandard sewer sizes.

101. Treatment of Sewage

a. *Type.* If treatment is required, the type of treatment and plant depend on the quantity and type of sewage, soil conditions, receiving waters, materials and labor available, and the climate. The Army Medical Service is responsible for determining the degree of treatment

required before disposal. Partial or complete treatment depends on the conditions controlling the disposal methods.

b. Site and Layout. The main consideration in selecting the treatment-plant site is the location of the final receiving ground or diluting water. The treatment plant should be downwind and far enough away from populated areas to avoid odor nuisance. Other factors influencing site selection are the elevation above floodwater level and the ground slope for gravity operation. Unless there is a 10- to 15-foot drop to provide gravity flow through complete treatment plants, the sewage is pumped. All treatment plants have a bypass for use during repair and maintenance. Plants which serve more than 5,000 persons are built generally with multiple tanks, filters, and other facilities, and the pipes are arranged so that parts of the plant can be bypassed for cleaning and repairing without putting the entire installation out of operation.

c. Capacity. Designs of tanks, basins, and other units within a treatment plant are based on the average anticipated flow for the required retention period. All pipes and channels within the plant are designed to carry the peak flow at velocities of not less than 2 feet per second.

d. Design. Standard designs for small sewage-treatment plants are shown in TM 5-302. When primary sedimentation and sludge digestion are sufficient to meet the needs for treatment of the sewage, only the Imhoff tank and sludge-drying beds are constructed, but if complete treatment is required, the trickling filter and final settling tank are also provided. This design criterion should be followed if larger plants are required. Important factors are the contributing population, settling time, filter loading, sludge-digestion capacity, and sludge-drying-bed area. The area required for sludge-drying beds with drains is $1\frac{1}{2}$ sq. ft. per capita; without drains it is $4\frac{1}{2}$ sq. ft. per capita.

102. Septic Tanks

Septic tanks may be used for small installations in isolated places where the soil is suitable for underground disposal, and where connection to a sewer system or discharge into a watercourse is not practicable. TM 5-302 shows a design of a septic tank, tile field, and leaching well, and design criteria for these facilities.

103. Surface Irrigation

a. Rate of Application. Disposal rates (rate of application) of sewage by surface irrigation vary with the permeability of the soil, ranging as high as 60,000 gallons per acre per day. To estimate the rate of application, dig a hole 1 foot square and 1 foot deep and fill it with water. When the water has seeped away but the bottom of the hole is still wet, pour 6 inches of water in the hole and note the time

required for the water level to drop 1 inch. This time in minutes corresponds to the permissible rates of sewage application shown in table 88, which are furnished only as a guide.

b. Ground Recovery. Ground used for surface irrigation must be rested. With use, the surface will clog and must be scraped off. Allowances for ground resting and recovery, field maintenance, and normal rainfall are included in the above table.

Table 88. Surface Irrigation; Gallons per Acre per Day

Time for water to fall 1 inch in test hole (minutes)	Average rate of application (gallons per acre per day)
1-----	57, 700
2-----	46, 800
5-----	34, 800
10-----	25, 000
30-----	12, 000
60-----	8, 700

104. Leaching Cesspools

Leaching cesspools are closed or covered pits, usually with masonry walls and an unlined bottom, through which liquids percolate into the surrounding soil. Solids settle to the bottom of the pit where they are digested. Occasionally, it may be necessary to pump or bail the sludge. Leaching cesspools range from 4 to 6 feet in diameter and from 6 to 20 feet deep. The depth of leaching cesspools is governed by the depth of permeable soil and the ground-water level. Masonry-lined walls are laid dry with open joints to within 4 feet of the surface. If more than one cesspool is required, they are connected in series and are located at least 20 feet apart. Size can be determined by filling a 1-foot-square hole with 6 inches of water, and allowing it to seep away. While the bottom of the hole is still wet, fill again to a depth of 6 inches and observe the time in minutes for the water in the test hole to fall 1 inch. The time in minutes is applied to the permissible rates shown in table 89, which are furnished only as a guide.

Table 89. Leaching Cesspools; Square Feet/Gallons Per Day

Time for water in test hole to fall 1 inch (minutes)	Required surface area of bot- tom and side walls in con- tact with sewage (square feet per 100 gallons per day)
1-----	19
2-----	23
5-----	31
10-----	44
30-----	91
60-----	111

105. Subsurface Irrigation

Settled sewage is disposed of by subsurface irrigation, a method commonly used in conjunction with cesspools or septic tanks at small installations. The main distributors are laid with tight, but not necessarily waterproof, joints. The tile pipe of the laterals, usually 4 to 6 inches in diameter, is laid end to end with a $\frac{1}{4}$ -inch space between lengths. The top two-thirds of the joint is covered with roofing paper to keep the soil from washing into the line. Perforated bitumenized fiber pipe, if available, is laid with tight end joints and perforations downward. Laterals are laid in a gravel-filled shallow trench with about a 6-inch fall per hundred feet for unregulated flow and about a 4-inch fall per hundred feet where a dosing system is used. Laterals are spaced 5 to 10 feet apart and are generally 75 to 100 feet long. To determine the length of the tile drain system, dig a 1-foot-square test hole to the depth of the proposed tile drains. Fill the hole with water to a depth of 6 inches and observe the seepage. While the bottom of the hole is still wet, fill again to a depth of 6 inches and observe the time in minutes for the water in the test hole to fall 1 inch. The time in minutes is applied to the permissible rates shown in table 90, which are furnished only as a guide.

Table 90. Subsurface Irrigation; Gallons Per Day Per Hundred Feet of 18-Inch Trench

Time for water to fall 1 inch in test hole (minutes)	Average rate of application (g.p.d. per 100 feet of trench 18 inches wide)
1.....	600
2.....	480
5.....	360
10.....	255
30.....	120
60.....	90

106. Chlorination

Where the condition exists that through failure of power or equipment there is a possibility of contaminating a water supply with raw sewage, provisions are provided for chlorinating at a rate of 200 pounds per million gallons at the 4-hour rate of sewage flow. In other cases where chlorination is required, provisions are made for chlorination at a rate of 125 pounds per million gallons at the 4-hour peak rate of flow. The 4-hour peak rate is considered to be 175 percent of the average daily rate of flow. Chlorine is sometimes used to delay the oxygen demand until the sewage reaches a body of water large enough to provide the oxygen required. It is also effective in killing pathogens if the contact period and the

chlorine concentration are sufficient, and all particles are finely enough divided to permit chlorine contact. The chlorine dosages given in table 91 are high and are designed to safeguard health and prevent serious nuisance in emergencies; they are substitutes for other processes of sewage treatment. Chlorine is applied by mechanical chlorinators or an improvised drum chlorinator. The data given in table 91 are based upon obtaining a chlorine residual of 0.5 parts per million after a contact time of 15 minutes.

Table 91. Sewage Chlorination Dosages

Type of sewage or effluent	Approximate dosage (pounds per day liquid chlorine per 1,000 persons)
Raw sewage-----	40
Settled sewage-----	30
Trickling-filter effluent-----	10
Surface- or subsurface-irrigation effluent-----	5

107. Maintenance of Sewers

a. Repair. Sewer repair consists principally of replacing broken manhole covers and ring assemblies and cracked or crushed lengths of pipe. Sections of bell-and-spigot clay pipe are installed by chipping off one-half the bell of the length to be inserted, chipping off upper portion of bell on the section of pipe below the gap, inserting the new section and rotating so the unchipped half of the bell is on the bottom, and completing the joint with mortar or mastic.

b. Methods.

- (1) *Stoppages.* The clearing of stoppages is the most important item of sewer maintenance. Tree roots, particularly poplars, willows, and elms, penetrate pipe joints and clog sewers. Large objects and deposits decrease or stop flow. Sluggish flow, accumulated scum, or sewage backed up in a manhole indicates that repair or cleaning is required.

- (2) *Methods.*

- (a) Sewers are cleaned by push rods, wooden balls, or flushing. Push rods 4 feet long are jointed and pushed through the sewer from manhole to manhole. Special tools are attached to the first rod to clear deposits or cut tree roots. The use of rods becomes difficult when the distance exceeds 300 feet.
- (b) Wooden balls of one-half or three-fourths the diameter of the pipe can be used to clean deposits from sewers. They are placed in the sewer and recovered by placing a coarse screen in the manhole downstream. The sewage

backed up behind the ball escapes around it at high velocity, scouring out solids deposited in the pipe.

- (c) Sewers are flushed out by damming the outlet in a manhole with a sandbag, and removing the bag with an attached rope after the manhole has partially filled. Backed-up sewage is then released to scour out deposits. Care is taken not to back up sewage into fixtures and inlets in buildings. Discarded fire hose also is used for flushing. Water pressure makes the hose stiff enough to be pushed through short lengths of pipe.

c. Safety. Sewer gas, methane, hydrogen sulfide, or gasoline and oil drainings can fill sewers with explosive mixtures. Carbon monoxide is particularly dangerous because it is often present in sewers and is not perceptible to the human senses. It may cause a slight headache preceding unconsciousness. Although some of the lighter gases are removed by opening manholes, the weight of carbon monoxide is about the same as air and it is removed only by using a blower. Sewer repair men should work in pairs, one staying above ground to observe and aid the other if necessary. A rope is sometimes tied around the man below ground to lift him out if he becomes unconscious. Chemical detectors for carbon monoxide are made, but if they are not available, a bird in a cage lowered into a manhole is observed for the effects of gas. A considerable concentration of carbon monoxide makes a man unconscious almost immediately, and death is avoided only by artificial respiration, immediately and properly administered.

Section III. REFUSE COLLECTION AND DISPOSAL

108. General

a. Refuse consists of garbage, rubbish, ashes, debris, and other domestic and commercial solid waste material.

- (1) Garbage is the animal vegetable waste and containers resulting from the handling, preparation, cooking, and consumption of foods.
- (2) Rubbish consists of discarded unsalvaged waste material such as metal, glass, crockery, floor sweepings, paper, wrappings, containers, cartons, and similar articles.
- (3) Ashes include the residue from burning wood, coal, coke, and other combustible material used in heating and cooking.
- (4) Debris consists of such items as grass cuttings, tree trimmings, stumps, street sweepings, roofing and construction wastes, and similar waste material resulting from construction, maintenance, and repair work.

b. Refuse collection and disposal are discussed in TM 5-634.

109. Methods of Disposal

Refuse is disposed of by burying in a sanitary fill, by incineration, by dumping at sea, or by contract with disposal services.

110. Collection

A regular schedule and system of collection is established to fit the particular disposal method. In all cases, stands are installed for cans used for storage of garbage. Military organizations must provide facilities at each messhall for the sanitary handling and storage of garbage until it is collected and for the proper cleansing of cans which are not removed by collectors (TM 5-634). The list of average weights of materials given in table 92 is a guide to handling collections.

Table 92. Average Weights of Garbage and Refuse Materials

Material	Weights (pounds)	
	Per 32-gallon can	Per cubic foot
Garbage-----	150 to 225-----	35 to 53.
Refuse without garbage or ashes-----	28 to 36-----	6.5 to 8.5.
Refuse including garbage-----	39 to 47-----	9 to 11.
Refuse including both garbage and ashes-----	56 to 64-----	13 to 15.
Ashes-----	141 to 158-----	33 to 37.

111. Disposal by Sanitary Fill

A sanitary fill is an effective method of permanently disposing of all types of waste including dry trash, incombustible rubbish, edible and nonedible garbage, in nearly any proportion. Waste materials are placed in a continuous series of sealed cells, compacted, and thoroughly sealed under 2 feet of dirt. The earth covering is obtained from succeeding trenches dug parallel to the original trench. The sanitary-fill method eliminates rat, fly, and mosquito hazards, and smoke and odors resulting from open fires and dumps. Burning materials in sanitary-fill trenches is not permitted because it greatly lessens the effectiveness of the installation and complicates operation. Complete details for the siting, construction, and operation of sanitary fills are given in TM 5-634. The depth of the original trench, and the depth of the compacted material, depend on the size of the installation using the fill and on the amount and kind of waste. Table 93 is a guide to be used in determining the depth of the original trench and the depth of the compacted material. Since the second and succeeding trenches are dug only to obtain enough dirt for a 2-foot covering over the compacted refuse in the preceding trench, they need not be over 3 feet deep.

Table 93. Depths, Sanitary Fills

Size of Installation	Depth of compacted refuse (feet)	Depth of original trench (feet)
1,000 to 2,000 men.....	3	2½
2,000 to 4,000 men.....	3½	3
4,000 to 6,000 men.....	4	3½
6,000 to 8,000 men.....	5	4
8,000 to 10,000 men.....	6	4

112. Disposal by Incineration

a. General. Incineration is the disposal of refuse by burning in specially constructed furnaces. Incineration destroys all organic matter, both gaseous and solid, and eliminates all substances likely to undergo bacterial decomposition. Garbage, rubbish, dead animals, and dried sludge from sewage disposal are burned in incinerators. Mixed refuse usually contains enough combustible material to provide the fuel for burning. Additional fuel is used when burning garbage alone.

b. Garbage is shoveled through a charging hole and onto an inclined drying hearth. Flames and hot gases produced by burning material on the grate dry the wet garbage on the drying hearth. As the garbage dries, it falls or is raked down to the burning grates where it burns and forms a solid mass or clinker. This clinker is broken up from time to time and removed to keep it from clogging the burning grate. The ash falls into a pit under the burning grate and it is removed when necessary. The ash is disposed of in open dumps.

c. Construction. One large centrally located incinerator for a base camp or hospital is generally more efficient than a separate small incinerator for each unit. However, when the construction of one central incinerator is not possible, several smaller incinerators are built. Occasionally, because of the limited capacity of incinerators, it is necessary to construct a battery of incinerators at the central location. Construction details for incinerators are given in TM 5-280 and TM 5-634.

d. Operation. For adequate drying and combustion, the incinerator is heated before attempting to dispose of garbage. A fire is started in the furnace with clean, dry rubbish saved from a previous operation or with wood or coal. After the furnace is hot, the wet refuse is placed on the drying grate at reasonable intervals. Care is taken not to overload the incinerator with wet garbage. As the garbage dries, it is moved toward the burning grate making room on the drying grate for the next charge of wet garbage. Garbage is stored as close to the charging holes as possible for ease in charging. To make the greatest use of the heat, the plant should be operated with as few shutdowns as

possible. The charging holes are kept open only when absolutely necessary, because the furnace cools rapidly. Tin cans carried into the furnace with the garbage are removed frequently to prevent decreasing the burning capacity of the grates. Glass, china, box straps, and other metal scrap are removed from the refuse before burning because they impair the efficiency of the incinerator.

e. Collection. Garbage is brought to the incinerators in cans or in truck bodies. The garbage is stockpiled at the charging hole from the cans or trucks. The collection schedule is arranged so lack of garbage does not stop the incinerator. The best collection time is during the forenoon.

113. Disposal by Dumping at Sea

Disposal by dumping at sea is not recommended where other methods can be used. It is most practicable for island installations, where the use of sanitary fills is impossible or the construction of incinerators is not feasible. Where islands are close to an inhabited friendly shore, or the body of water is relatively small, disposal by dumping at sea is inadvisable. When dumping in large bodies of water, the direction of prevailing winds and currents is considered so as to prevent return of the garbage to shore and to avoid defiling shores elsewhere. The garbage is loaded directly from cans or trucks onto the barge, scow, or other means of transportation, hauled at least 5 miles offshore, and dumped.

114. Disposal of Refuse Alone

a. General. Garbage type incinerators and sanitary fills are not practicable for disposing of large amounts of crating, scrap lumber, street sweepings, and incombustible trash. Crating and lumber produce too much heat for ordinary incinerators. The two common methods of disposing of refuse alone are burning pits and regulated dumps.

b. Burning Pits. Masonry or earth pits of varying size and design to meet local requirements are used to burn combustible refuse. However, they are fire hazards and their construction and method of operation must be approved by all fire-protection agencies. The pits are cleaned weekly and all ashes, metal, and other incombustibles are disposed of on regulated dumps. The design of earthen pits depends on the terrain and the quantity of refuse to be burned. A suggested design is a revetment with two horseshoe-shaped cells; each cell is used alternately for dumping and burning. If the pit is large, the ashes are left in the bottom, but periodically they are leveled with a bulldozer or scraper. If the area of the pit is limited, the ashes and incombustibles are removed and placed on a regulated dump.

c. *Regulated Dumps.* Regulated dumps are used to dispose of incombustible trash. They are built like embankments or highway fills of limited height and area and situated so that they are compacted daily by truck traffic. They are leveled periodically by a bulldozer and kept orderly and free of objectionable contents. If properly operated, regulated dumps are used to reclaim worthless land. Refuse is not dumped over an embankment or the brow of a hill making a high-face dump, because dumps of this kind are difficult to operate under regulated-dump standards.

Section IV. ELECTRIC-POWER DISTRIBUTION

115. General

Electric transmission and distribution is discussed in detail in TM 5-765. Power generation in the field is developed in TM 5-766.

116. Foreign Voltages and Frequencies

Electric current for lights, motors, and other appliances is usually used at voltages of 115 or 208 volts and distributed at multiples thereof, but there are important exceptions; e.g., the prevailing voltage in Japan is 100. As to the frequencies in alternating current, the lower frequencies permit higher power factors in certain types of motors but cause flicker in incandescent light. The present standard frequency in the United States is 60 cycles, except that 25-cycle current is used for power in some industrial installations. In Europe, a frequency of 50 cycles for illumination and 25- and 42-cycle current for power are standard. Direct-current voltages and alternating-current voltages and frequencies generally used in various countries are given in table 94 (low-voltage supplies only).

117. Single-Phase Systems

Buildings containing single-phase equipment, such as lights, X-ray machines, or single-phase motors are served by two- or three-wire systems. Small loads as required for barracks lighting are served by two-wire systems; large loads require three-wire service.

a. *Two-Wire Systems.* In single-phase systems using two wires, the current in one wire always equals the current in the other, but flows in the opposite direction. Currents in the two wires reverse simultaneously.

b. *Three-Wire Systems.* Single-phase systems of three wires supply two voltages simultaneously. One wire is the neutral and is grounded; the other two are the hot wires. Figure 50 shows a typical single-phase three-wire system.

Table 94. *Worldwide Direct-Current and Alternating-Current Voltages*

Continent and country	Direct-current voltage		Alternating-current voltage		Frequency	
	Prevailing	Other	Prevailing	Other	Prevailing	Other
North America:						
United States.....	120/240.....	115/230, 500, 600....	120/208, 120/240 *....	110/220, 115/230, 220/440, 230/460, 240/480.	60	25
Alaska.....	(b).....	(b).....	120/240 *.....	110/220, 115/230, 120/208.	60	(b)
British Honduras.....	110/220 *.....	(b).....	(b).....	(b).....	(b)	(b)
British West Indies:						
Antigua.....	220 *.....	(b).....	(b).....	(b).....	(b)	(b)
Bahamas.....	(b).....	(b).....	115 *.....	110, 120, 220.....	60	(b)
Barbados.....	(b).....	(b).....	110 *.....	(b).....	60	(b)
Bermuda.....	(b).....	(b).....	110/220 *.....	(b).....	60	(b)
Dominica.....	220 *.....	(b).....	(b).....	(b).....	(b)	(b)
Grenada.....	(b).....	(b).....	230 *.....	(b).....	50	(b)
Jamaica.....	(b).....	(b).....	110/220 *.....	(b).....	40	(b)
Saint Kitts.....	(b).....	(b).....	110 *.....	(b).....	60	(b)
Trinidad.....	(b).....	(b).....	110/230 *.....	(b).....	60	(b)
Canada.....	(b).....	(b).....	110/220 *.....	115, 120, 230, 550, 575.	60	25
Costa Rica.....	(b).....	(b).....	110/220 *.....	(b).....	60	(b)
Cuba.....	(b).....	(b).....	110/220/440 *.....	115.....	60	(b)
Dominican Republic.....	(b).....	(b).....	110/220/440 *.....	120/240.....	60	(b)
French West Indies:						
Guadeloupe.....	(b).....	(b).....	110 *.....	(b).....	50	(b)
Martinique.....	(b).....	(b).....	110/220 *.....	(b).....	50	(b)

Guatemala	220	(b)	110/220 a	230/400	60	50
Haiti	440/500	(b)	115 a	110/190, 220/230, 380, 440/500.	60	50
Honduras	120/220	(b)	110/220 a	(b)	60	(b)
Mexico	(b)	(b)	110/125 a	115, 120, 216, 220	60	50
Netherlands West Indies:						
Aruba	(b)	(b)	115/120 a	110/220	60	(b)
Curacao	(b)	(b)	125 a	220	50	(b)
Newfoundland	(b)	(b)	110/220 a	(b)	60	(b)
Nicaragua	110/125	(b)	110/220 a	(b)	60	(b)
Panama, Republic	(b)	(b)	110/220 a	(b)	60	50
Panama Canal Zone	(b)	(b)	110 a	(b)	25	(b)
Puerto Rico	(b)	(b)	115/230 a	120/240, 220/440	60	(b)
El Salvador	110	(b)	110/220 a	(b)	60	(b)
Virgin Islands	(b)	(b)	120/240 a	(b)	60	(b)
South America:						
Argentina	220	235, 380, 550	220 a	225/390, 380, 440	50	25, 60
Bolivia	110/220	(b)	110/220 a	127, 230, 240	50	60
Brazil	220	(b)	120/220 a	110, 115, 127	50	60
Chile	220	240	220 a	110, 380	50	60
Colombia	(b)	(b)	110/220 a	115, 150, 230, 260 380.	60	50
Ecuador	220	(b)	110/220 a	380	60	50
Guiana, British	(b)	(b)	115/230 a	110/220	50	60
Guiana, Dutch (Surinam).	(b)	(b)	125 a	220, 440	50	60
Guiana, French	(b)	(b)	110 a	(b)	50	(b)
Paraguay	220	(b)	220 a	(b)	50	(b)
Peru	220	110	220 a	110, 115, 230, 240, 380/500.	60	50
Uruguay	(b)	(b)	220 a	(b)	50	-(b)
Venezuela	(b)	(b)	110/220 a	120, 240	50	60

See footnotes at end of table.

Table 94. *Worldwide Direct-Current and Alternating-Current Voltages—Continued*

Continent and country	Direct-current voltage		Alternating-current voltage		Frequency	
	Prevailing	Other	Prevailing	Other	Prevailing	Other
Europe:						
Albania.....	125.....	150.....	220 ^a	125, 150, 380.....	50	(^b)
Austria.....	220.....	110, 440, 550, and others.	220/380 ^a	125/220, 110/220, 125, 120, 110, and others.	50	(^b)
Azores.....	220.....	(^b).....	(^b).....	(^b).....	50	(^b)
Belgium.....	110.....	220/440.....	220 ^a	110, 127, 135, 190, 380.	50	(^b)
Bulgaria.....	220.....	440.....	220 ^a	120, 150, 380.....	50	(^b)
Czechoslovakia.....	110/220.....	120, 150, 440, and others.	220 ^a	110, 115, 127, 380, and others.	50	42
Denmark.....	220.....	110, 440, 550.....	220 ^a	110, 120, 208, 380.....	50	(^b)
Finland.....	120.....	220.....	220/380 ^a	110, 120, 208, 115, 127, 190.	50	(^b)
France.....	110/220.....	120, 190, 380, 440, 550.	127/220 ^a	110 to 120, 150, 190, 200, 208, 380.	50	25
Germany.....	220.....	110, 440, and others.	220/380.....	110 to 127 and others.	50	25
Gibraltar.....	440.....	(^b).....	240.....		50	(^b)
Greece.....	220.....	110, 440.....	127.....	110, 150, 220, 380.....	50	25, 42
Hungary.....	220.....	110, 120.....	220 ^a	110, 115, 120, and others.	50	42
Iceland.....	(^b).....	(^b).....	220.....	(^b).....	50	(^b)
Ireland.....	220.....	(^b).....	220 ^a	200, 380.....	50	(^b)

Italy	220	110, 150, 380, 440, 550, and others.	125/220 ^a	120, 127, 150, 260 and others.	50	(b)
Luxembourg	110, 220 ^a	(b)	220, 380 ^a		50	(b)
Malta	(b)	(b)	105	210	100	(b)
Monaco	(b)	(b)	110, 115	(b)	42	(b)
Netherlands	220	127	220 ^a	127, 380	50	(b)
Norway	220	110, 440	220 ^a	230, 130, 110, 120, 150, 380.	50	25, 45
Poland	220	110, 500, 600	220 ^a	110 to 127	50	(b)
Portugal	220	440	110 ^a	190, 220, 380	50	(b)
Rumania	220, 220/440 ^a	110, 120, 150	110, 220, 220/380	190, 208, 380, 550	50	42
Spain	110	120, 130, 150, 240, 220, 300.	110 to 130 ^a	150, 220, 440, and others.	50	
Sweden	220	110, 120, 220/440, and others.	220/380, 127/220 ^a	110, 110/190 and others.	50	25
Switzerland	220	160, 440, 600, and others.	220/380, 220, 380 ^a	110/190, 125, 145/ 250, and others.	50	(b)
Trieste	(b)	(b)	220, 380, 500 ^a	(b)	42	(b)
Turkey	220	110	220	110, 190/380	50	(b)
Union of Soviet So- cialist Republics.	220	115, 250, 440	110/220	380	50	(b)
United Kingdom	230	220, 440	230 ^a	220, 240, 250	50	40, 25
Vatican City	(b)	(b)	125	220	45	(b)
Yugoslavia	110	120	220 ^a	150 to 127, 150, 190, 380.	50	42
Asia:						
Aden	(b)	(b)	230/400	(b)	50	(b)
Afghanistan			220/380	230	50	60
Arabia	(b)	(b)	110/220/440	120/240, 250/433	60	50
Bhutan	220 ^a	440	120/220	380/440	60	(b)

See footnote at end of table.

Table 94. Worldwide Direct-Current and Alternating-Current Voltages—Continued

Continent and country	Direct-current voltage		Alternating-current voltage		Frequency	
	Prevailing	Other	Prevailing	Other	Prevailing	Other
Asia—Continued						
British Malay:						
Malayan Federation.	(b)-----	(b)-----	230/400-----	-----	50	40, 60
North Borneo-----	(b)-----	(b)-----	230/400-----	-----	60	50
Singapore-----	230-----	-----	230/400-----	230/460-----	50	-----
Burma-----	220 ^a -----	220/440, 250/550-----	230/400-----	220, 230, 420-----	50	60
Ceylon-----	220/230-----	(b)-----	230/400-----	230/416, 220/230, 240/416.	50	-----
China-----	220/440 (in Hankow).	110-----	220/380-----	110/220, 110/190, 120/300, 200/350, 220, 220/440.	50	60, 25
Cyprus-----	220 ^a -----	(b)-----	110-----	(b)-----	50	(b)
Taiwan-----	(b)-----	(b)-----	100/200-----	(b)-----	60	(b)
French Indochina-----	110-----	240, 120, 220-----	120, 208-----	127/220, 220, 240, 110, 115.	50	(b)
Hong Kong-----	(b)-----	(b)-----	200/346-----	(b)-----	50	(b)
India-----	220/440-----	220, 230, 225/450, 250/500, 230/460.	230/400-----	200, 230, 220/380, 250/440.	50	25
Indonesia:						
Borneo-----	110-----	(b)-----	127-----	110, 125-----	50	(b)
Celebes-----	(b)-----	(b)-----	127-----	220-----	50	(b)
Moluccas and Minor Soenda Isles.	(b)----- [?]	(b)-----	127-----	(b)-----	50	(b)

Java and Madura	(b)	(b)	127/220	110/190, 220/380	50	(b)
Sumatra	220	(b)	127/220, 127	110/190, 220/380	50	(b)
Iran	220	110	220	380	50	(b)
Iraq	220	440	220	380	50	(b)
Israel	(b)	(b)	220/380	230/400	50	(b)
Japan	100	(b)	100/200		^c 50, 60	(b)
Jordan	(b)	(b)	220/380	(b)	50	(b)
Korea	(b)	(b)	100/200		60	(b)
Lebanon	(b)	(b)	110/190	220/380	50	(b)
Manchuria	(b)	225	110/220	(b)	50	25, 60
Nepal	(b)	(b)	120/220	380/440	60	(b)
Pakistan	220	(b)	230/400	220, 220/380	50	(b)
Philippines	(b)	(b)	220	110/220	60	(b)
Syria	110/220	(b)	110/220 ^a	200, 115, 190	50	(b)
Thailand (Siam)	220	110, 120, 550	110/220	220, 230, 380	50	(b)
Turkey	220	110	220	110, 190/380	50	(b)
Africa:						
Angola	(b)	(b)	(b)	220/380	50	(b)
Algeria	(b)	(b)	127/220, 220/380 ^d	115/200, 230/400, 500, 110. ^d	50	(b)
Belgian Congo	(b)	(b)	220/380	(b)	50	(b)
British West Africa:						
Gambia	(b)	(b)	230	(b)	50	(b)
Ghana (Gold Coast)	220 ^a	(b)	230	(b)	50	(b)
Nigeria	(b)	(b)	230/400 ^d	(b)	50	(b)
Sierra Leone	(b)	(b)	230/400	(b)	50	(b)
British East Africa:						
Canary Islands	None		110, 115	190, 220	50	-----
Kenya	(b)	(b)	415/240	(b)	50	(b)
Mauritius	(b)	(b)	230	400	50	(b)
Tanganyika	220	(b)	230/400	(b)	50	(b)
Uganda	(b)	(b)	240/415	(b)	50	(b)
Zanzibar	220	(b)	(b)	(b)	50	(b)

See footnotes at end of table.

Table 94. *Worldwide Direct-Current and Alternating-Current Voltages—Continued*

Continent and country	Direct-current voltage		Alternating-current voltage		Frequency	
	Prevailing	Other	Prevailing	Other	Prevailing	Other
Egypt-----	220 ^a -----	110, 440-----	220-----	100/220, 110/220, 380.	50	40
Ethiopia (including Eritrea).	(b)-----	(b)-----	125/220, 127/220 ^a ---	220/380-----	50	(b)
Federation of Rhodesia and Nyasaland:						
Northern Rhodesia---	(b)-----	(b)-----	220/380-----	(b)-----	50	(b)
Nyasaland-----	(b)-----	(b)-----	230/400-----	(b)-----	50	(b)
Southern Rhodesia---	(b)-----	(b)-----	220/380, 230/400---	(b)-----	50	(b)
French Cameroons-----	(b)-----	(b)-----	115/200-----	(b)-----	50	(b)
French Equatorial Africa---	(b)-----	(b)-----	127/220-----	220/380-----	50	(b)
French West Africa-----	(b)-----	(b)-----	127/220-----	220/380-----	50	(b)
Liberia-----	(b)-----	(b)-----	115-----	220-----	60	(b)
Libya-----	(b)-----	(b)-----	125-----	220-----	50	(b)
Madagascar-----	(b)-----	(b)-----	127/220-----	(b)-----	50	(b)
Morocco (southern zone)---	(b)-----	(b)-----	115/200-----	230/400, 110/190, 500.	50	(b)
Morocco (northern zone)---	(b)-----	(b)-----	127/220-----	(b)-----	50	(b)
Morocco (Tangier zone)---	(b)-----	(b)-----	110/190-----	(b)-----	50	(b)
Mozambique-----	220-----	240, 250, 480, 550---	220/380-----	110/190, 120, 220/ 440, 230, 240.	50	(b)
Seychelles Islands-----	220-----	(b)-----	(b)-----	(b)-----	(b)	(b)
Sudan-----	500-----	(b)-----	240/415-----	230-----	50	(b)
Trust Territory of Somali- land.	120-----	(b)-----	230-----	127/220, 220/230---	50	(b)
Tunisia-----	(b)-----	(b)-----	115/200-----	110/190, 220/380, 230/400.	50	(b)

Union of South Africa	220	220/440, 230, 230/460, 240, 250, 250/500.	220/380	100, 120, 200, 230, 240, 250, 280, 380, 400, 500.	50	(b)
Australia and Oceania:						
Australia:						
New South Wales.	240	(b)	240	415 b	50	(b)
Queensland	220	220/440, 240	240	415 b	50	(b)
South Australia	200	220, 230	200	230, 240	50	25
Tasmania	230	480 b	240	415 b	50	(b)
Victoria	230	(b)	230	(b)	50	(b)
West Australia	220	110, 230	250	(b)	40	(b)
Oceania:						
Fiji Islands	240/480	110, 250	240/415	(b)	50	(b)
Guam	(b)	(b)	110/220 a	(b)	60	(b)
Hawaii	(b)	(b)	120/208/240/480 a	(b)	60	(b)
New Caledonia	(b)	(b)	125	110/220	50	(b)
New Zealand	230	230/460, 500	230/400	220/240	50	(b)
Samoa Islands of Upolu and Savaii under New Zealand administra- tion.	(b)	(b)	110/220	(b)	50	(b)
Other Samoa Islands.	(b)	(b)	110	(b)	50	(b)
Tahiti	(b)	(b)	110	(b)	60	(b)

a Indicates prevailing voltage-current combination.

b Indicates, as a rule, that no further research has been performed, since prevailing voltage and frequency have been indicated.

c Southern Japan, 50. Northern Japan, 60.

d Prevailing voltages in Algeria are 220/380 where possible, 127,220 elsewhere. The 110, 115/200, and 230/400 voltages are being changed to the prevailing standards. The 500 voltage is used for tramways and for rural distribution.

Note. 125/250 indicates that voltages are associated. This has been added where sources indicated such condition.

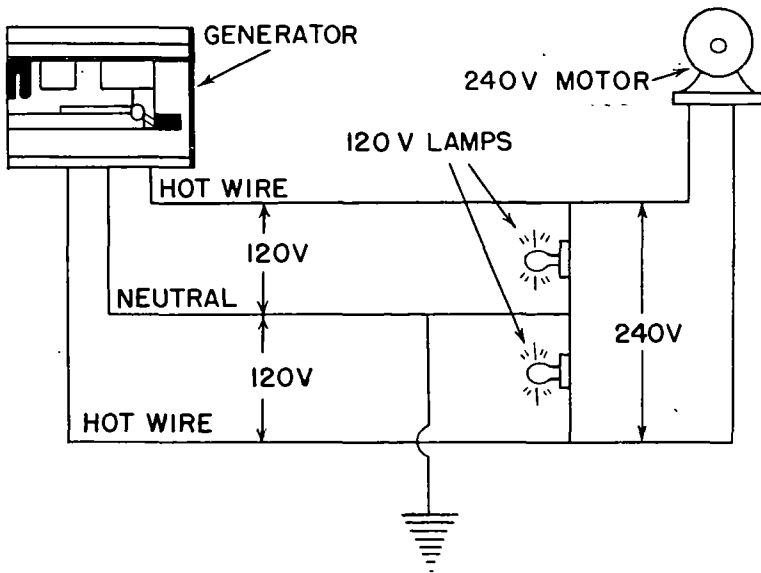


Figure 50. Single-phase, three-wire system.

- (1) *Voltages.* The voltage between the two hot wires equals the sum of the voltages between the neutral and each hot wire. Usually, the voltage between the two hot wires is twice the voltage between the neutral and either hot wire.
- (2) *Currents.* The current in the neutral wire equals the difference between the currents in the hot wires, as shown in figure 51. Current flows in the neutral wire in the same direction as the current in the hot wire carrying the smaller current. If total watts of load connected between the neutral and the two hot wires are equal, the loads are balanced. Under this condition, desirable in electric distribution systems, the current in one hot wire equals the current in the other and no current flows in the neutral.

118. Two-Phase Systems

The two-phase system has two single-phase currents having a difference in phase of 90° . It is sometimes called "quarter-phase system." The currents are distributed on the three-wire, four-wire, or five-wire system. This system is not in common usage except in certain localities. Further information may be obtained from the American Electricians' Handbook.

119. Three-Phase Systems

A three-phase system is three single-phase systems interlocked so the current in each phase reverses at a different instant than the current in either of the other two phases. Three-phase systems using

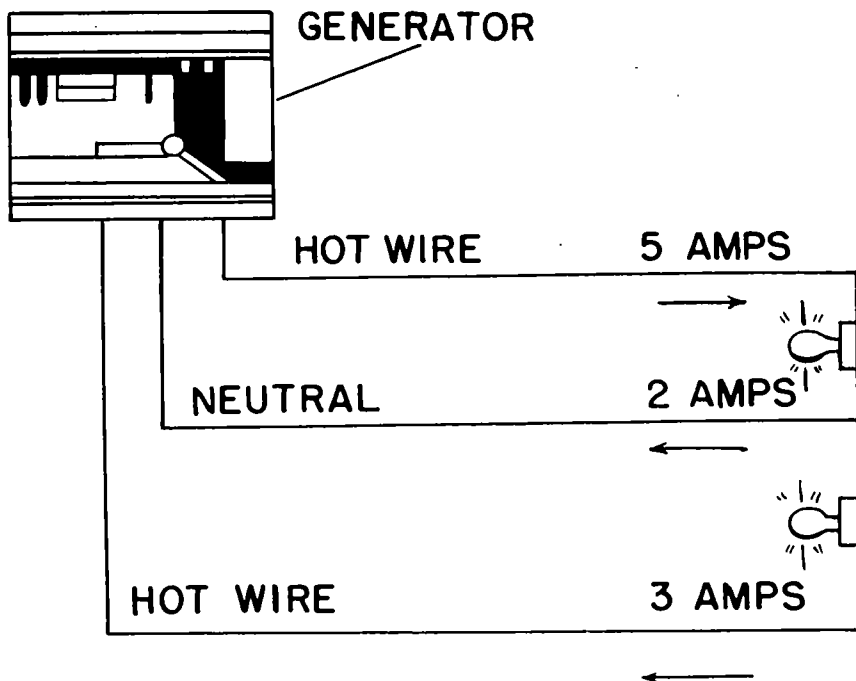


Figure 51. Current in neutral wire.

three-phase wires and one neutral wire provide a flexible means of obtaining both lighting and power from the same circuit and are commonly used. When power only is required the neutral may be omitted. Three-phase systems are better suited than single-phase systems to heavy loads, especially large motors. Figure 52 shows a typical three-phase four-wire system.

a. Voltages. Two voltages are available simultaneously from a three-phase four-wire system, the phase-to-neutral voltage and the phase-to-phase voltage.

- (1) *Phase-to-neutral* voltage is the voltage between any phase wire and the neutral.
- (2) *Phase-to-phase* voltage is the voltage between any two phase wires. Phase-to-phase voltage equals 1.73 multiplied by the phase-to-neutral voltage.

b. Currents. As in the single-phase system, the loads between the neutral and each phase wire are balanced to reduce current in the neutral to a minimum. A perfectly balanced three-phase system carries equal currents in the phase wires and no current in the neutral.

120. Comparison of Systems

Systems are identified by the number of phases and wires and the voltages between wires. For example, in the single-phase three-wire

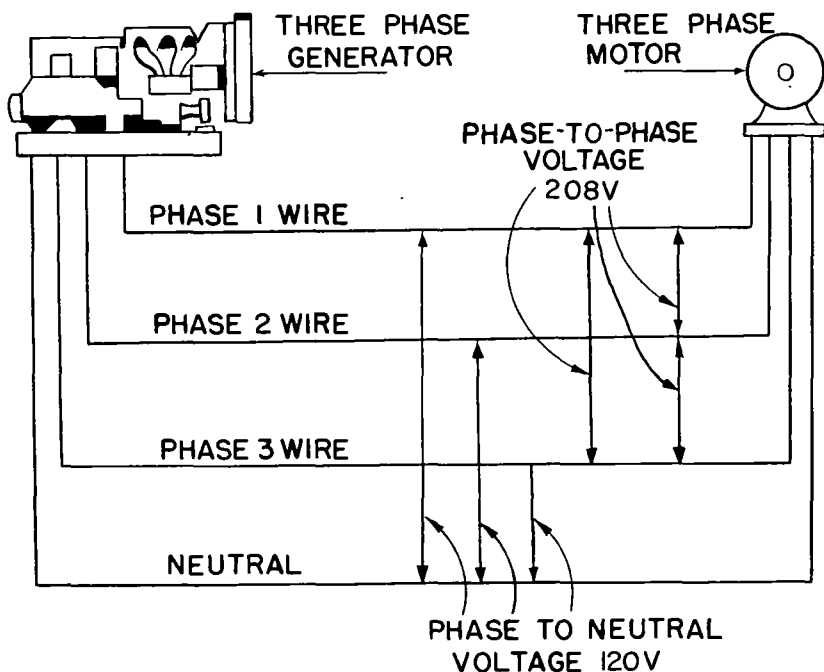


Figure 52. Three-phase four-wire system.

system, the voltage is 120 volts from hot wire to neutral, and 240 volts between hot wires. This notation is abbreviated 1ϕ 3w 120/240v. The three-phase four-wire system shown in figure 52 is abbreviated 3ϕ 4w 127/220v. Standard electrical symbols are given in detail in TM 5-680.

121. Electric-Power Requirements

a. General. Predetermine the maximum demand in kilowatts and the average consumption of energy in kilowatt hours when selecting a suitable power supply, specifying the proper equipment, and computing the cost of electricity.

b. Maximum Demand. The most accurate means of estimating the demand is to determine the connected load and apply suitable diversity factors. These factors are based on experience with projects similar in character and size to that under consideration. A breakdown of large projects and a classification of the types of service required may be helpful in estimating the total maximum demand and in applying the data obtained from other projects containing facilities of similar nature but not necessarily of the same size and composition. In general, the maximum 30-minute demand for the entire electrical system at posts, camps, and airfields will be approximately 30 percent of the total connected load, and at storage depots will be approximately 200 kilowatts per million square feet of ware-

house area. For industrial plants, the maximum demand should be determined from data furnished by the using service. On a per capita and bed basis, the following demands will be sufficiently accurate for preliminary estimating purposes:

Army camps.....	0.3 kw. per capita
Air Force tactical bases.....	0.3 kw. per capita
Air Force strategic bases.....	0.3 kw. per capita
Research and development bases.....	1.3 kw. per capita
Technical schools.....	0.6 kw. per capita
Repair schools.....	1.5 kw. per capita
Hospitals.....	2.0 kw. per bed

In applying the above figures to a specific project, special applications must be considered. Where other than normal loads are to be supplied, allowances must be made for the demands that will be imposed by these loads.

c. Consumption. The average monthly consumption should be computed by multiplying the maximum demand by a suitable load factor and by the number of hours the facility will be in operation during the month. The load factor will usually be between 30 and 45 percent at posts, camps, airfields, and storage depots. For instance, at an Army post having a total connected load of 8,000 kilowatts, the estimated maximum demand would be $8,000 \times 0.30 = 2,400$ kilowatts. Using a load factor of 45 percent, the estimated average monthly consumption would be $2,400 \times 0.45 \times 720 = 777,600$ kilowatt-hours. Similarly, using the per capita basis, at an Army post having an authorized strength of 8,000 men, the estimated maximum demand would be $8,000 \times 0.3 = 2,400$ kilowatts. Again using a load factor of 45 percent, the estimated average monthly consumption would be $2,400 \times 0.45 \times 720 = 777,600$ kilowatt-hours.

122. Transformers

a. General. A transformer receives electrical energy from one circuit and transfers it to another circuit by magnetic action. The circuit from which energy is received is called the primary; the receiving circuit is the secondary. Usually the primary and secondary circuits are at different voltages. An elementary transformer consists of a primary and a secondary coil surrounding an iron core. Alternating current in the primary coil produces an alternating magnetic field in the iron core. A voltage is induced in the secondary coil by the alternating field.

b. Substation Transformers. Substation transformers should be of the outdoor type and of applicable self-cooled rating selected from standard transformer KVA ratings.

- (1) *Standard KVA ratings in single-phase transformers* are: 3, 5, 10, 15, 25, 37.5, 50, 75, 100, 167, 250, 333, 500, 833, 1,250, 1,667, 2,500, 3,333, 5,000, 8,333, 12,500, 16,667, 20,000, 25,000, and 33,333.

- (2) *Standard KVA ratings in three-phase transformers* are: 9, 15, 30, 45, 75, 112½, 150, 225, 300, 500, 750, 1,000, 1,500, 2,000, 2,500, 3,750, 5,000, 7,500, 10,000, 15,000, 25,000, 37,500, and 50,000.

c. *Transformers Available in Oversea Depots.* The following transformers are currently stocked in overseas depots:

Transformer, Current, Indoor, 25 to 125 Cycles, 1 Phase, Current Rating Primary, 200 AMP, Secondary 5 AMP, 1½ In. Lg, ¾ In. Dia, 2 Wire Lead Type Terminals.	Std
Transformer, Current, Indoor, 25 to 125 Cycles, 1 Phase, Current Rating Primary, 500 AMP, Secondary 5 AMP, ¾ In. Lg, ¾ In. Dia, 2 Wire Lead Type Terminals.	Std
Transformer, Power, Distribution, 3 KVA Continuous, Self-Cooled, 55 Deg C Rise Above Ambient Temp, 230 V Nom High, 50 Cycle, Single Phase, 125 V Nom Low, 50 Cycle, Single Phase, Tapped At 115 V And 120 V, 2 Wire Service.	Std ASF
Transformer, Power, Step-Down, Input Primary, 3,000 V, 60 Cycles, 1 Phase, Output Secondary, 600 V, 6.6 AMP, 4 Wire Lead Type Terminals.	Std

123. Generators

a. Table 95 lists the alternating-current and direct-current generators available under the current standardization plan, although other miscellaneous generators still exist in supply channels. These standard generators are capable of supplying the power requirements of all power demands in the field.

b. The small alternating-current generators of 0.15-, 0.5- and 1.5-kw output ratings deliver 120-volts single-phase at frequencies of 60- or 400-cycles. The 1.5-kw, 60-cycle unit is the most versatile and widely used because its output is adequate for the communications and lighting requirements of small units in the field.

c. The alternating-current generators rated at power outputs of 3-, 5-, and 10-kw are all driven with gasoline engines, deliver 60- or 400-cycle ac, and have a change-over panel which permits connection for 120-208 volts, 3-phase, 4-wire, 120-volt, 3-phase, 3-wire, 120-volt, single phase, 2-wire; or 120/240-volt, single phase, 3-wire operation, each at the full rated kilowatt output. Because of this flexibility and range of power outputs, the 60-cycle group is quite versatile for general power requirements. The 10-kw, 60-cycle is the most versatile since its output is adequate for relatively large loads such as required by small maintenance shops. These generators are skid-mounted and usually covered with a protective housing.

d. Alternating-current generators of larger capacities up to 150-kw, are rated at 15-kw, 45-kw, 60-kw, 100-kw, and 150-kw and deliver 60- or 400-cycle, 3-phase, 4-wire power at 120/208 or 240/416 volts.

Output at 50 cycles is possible at 83 percent of the rated power output at 60 cycles. In addition to a diesel-driven model in each power rating, the 15-kw and 30-kw units are available with gasoline-engine drive. The availability of both diesel and gasoline types can be an important advantage where one or the other fuel may be unobtainable or required. For example, a motor pool requiring only gasoline could well use a gasoline-driven generator for electric power, thereby simplifying fuel supply. The 60-kw diesel-driven generator is probably the most widely used of the larger generators. Because the weight of the 60-kw units represents an easily-handled load for a 2½-ton truck, whereas larger generator units require a less readily available 5-ton truck, several 60-kw units are frequently used in parallel to supply large loads.

e. The direct-current generators listed are used for such purposes as starting Army aircraft, battery charging, operation of communication equipment, and as spare units to start heavy ground equipment. The majority of these units are gasoline driven and are easily transportable.

124. Power Systems

a. Load Estimation.

- (1) *Connected load.* Load estimation covers both the size and location of the items making up the connected load. The structures to be served are identified and marked on an accurately scaled map of the area. The connected load for each structure is then established and tabulated. The connected load is the sum of the electric-current requirement of each motor, light, and other electrically operated devices, expressed in kilovolt-amperes (kv.-a.). One thousand watts in incandescent lamps, or 1 horsepower of motor or power load is taken as 1 kv.-a. in estimating the connected load. The connected light and power loads for various standard buildings are given in TM 5-302. Connected loads for other structures may be estimated by comparing floor areas.
- (2) *Demand load.* The connected load is converted to demand load by applying a demand factor which is based on experience. The term load or demand, used alone, means demand load, in kv.-a., required to serve a given connected load. It is less than the connected load because all of the lights or other electric devices are not in use simultaneously. The demand factor is the ratio of the maximum demand of a system, or part of the system, under consideration. Demand factors for military structures are shown in table 96. Using these, the demand for each structure is computed and tabulated.

Table 95. Family of Engine-Generators

Frequency	Alternating current										Direct current			
	60-cycle						400-cycles							
Voltage.....	120		120/208		120/208, 240/416		120/208		120/208, 240/416		28		120	
Phase.....	1		1 & 3		3		1 & 3		3					
Wires	2		* 4		4		4		4		2		2	
Fuel.....	G	D	G	D	G	D	G	D	G	D	G	D	G	D
KW rating:														
0.15.....	x													
0.5.....	x						x				x			
1.5.....	x						x				x			
3.....			x				x				x			
5.....			x				x				x		x	
10.....			x				x				x			
15.....					xi	xi			x	x	x	**x		
30.....					xi	xi			x	x				
45.....						xi				x				
60.....						xi				x				
100.....						xi								
150.....						xi								

G—Gasoline driven. D—Diesel driven.

i—These generators to produce either 50- or 60-cycle current.

*—Panel connections permit, at rated KW output: 120/208 v 3-phase 4-wire, 120 v

3-phase 4-wire, 120 v 3-phase 3-wire, 120 v single phase 2-wire, 120/240 v single phase 3-wire.

**—Still in early stages of development.

Table 96. Demand Factors, Military Structures

Structure	Demand factor
Housing-----	0.9
Aircraft maintenance, facilities-----	.7
Operation facilities-----	.8
Administrative facilities-----	.8
Shops-----	.7
Warehouses-----	.5
Medical facilities-----	.8
Theaters-----	.5
NAV aids-----	.7
Laundry, ice plants, and bakeries-----	1.0
All others-----	.9

(3) Horsepower limits of electric motors by systems and voltages are shown in table 97.

(4) *Standard horsepower ratings of motors* are: $\frac{1}{20}$, $\frac{1}{2}$, $\frac{1}{8}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2, 3, 5, $7\frac{1}{2}$, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1,000, 1,250, 1,500, 1,750, 2,000, 2,250, 2,500, 3,000, 3,500, 4,000, 4,500, and 5,000.

b. Generator Location and Capacity.

(1) *Location.* To reduce wire requirements, generators are located preferably near points of large demand such as laundries, machine shops, bakeries, ice plants, and X-ray equipment. Generator locations are selected tentatively by map study of the plotted demands. The size of the area served by each low-voltage generator or transformer depends upon the type and location of the demands. In general, small demands such as barracks lighting are served efficiently at distances up to 1,500 feet, moderate demands such as mess structures, up to 1,000 feet. Generators are located on firm ground and along existing roads. Concrete foundations are justified for semipermanent installations of 30-kilowatt or larger generators.

(2) *Capacity.* Generator capacity is based on the sum of the demands served but is less than the sum because the peak demands are not simultaneous. The sum of the individual demands, in kv.-a., is multiplied by a generator factor to determine the required generator capacity in kilowatts. The factor allows for both the power factor (pf) of the generator and for the noneincidence of demands. Generator factors for theater-of-operations construction are given, in table 98. The diversity factor is discussed in TM 5-765.

Table 97. *Horsepower Limits*¹

System	Voltages	Minimum horsepower	Maximum horsepower
Alternating current, single phase-----	110-115-120	None	1½
	220-230-240	None	10
	440-550	5	10
Alternating current, two and three-phase--	110-115-120	None	15
	220-230-240	None	200
	440-550	None	500
	2200	40	None
	4000	75	None
	6600	400	None
Direct current-----	115	None	30
	230	None	200
	550-600	½	None

¹ Reprinted from American Electricians' Handbook by Terrell Croft by permission of McGraw-Hill Company. Copyright 1942.

(3) *Number of generators.* Enough excess generator capacity is provided to supply the maximum demand with the largest generator out of service. In small systems, generators are preferably of the same size and type, for interchangeability and to reduce the requirements for spare parts. In larger systems, generators of different sizes are justified to permit more efficient operation. For example, if a 100-kilowatt lighting demand is served by one 30-kilowatt, one 70-kilowatt, and one 100-kilowatt generator, any one generator can be out of service at any time; and the 30-kilowatt generator will probably supply the entire demand in daytime hours.

(4) *Interconnection.* Generator locations in hospital areas and refrigeration warehouse areas are usually interconnected in insure uninterrupted service. Interconnections require additional copper and are not justified except in hospital and refrigeration areas. If the supply of generators does not permit either interconnection or standby capacity as described in (3) above, the operating rooms and one or two lights per ward are wired on a special circuit to a small emergency generator.

c. Transformer Location and Capacity. Transformers are required wherever the utilization voltage differs from the transmission or distribution voltage. Their location is influenced by the same factors which affect generator locations (b(1) above). The proper transformer capacity in kv.-a. is the same as the full demand in kv.-a.

Table 98. Generator Factors, Theater-of-Operations Construction

Type of load	Generator factor
Lighting-----	1. 00.
Predominantly lighting with some motors-----	. 95
Lighting with ranges and water heaters-----	. 95
Lighting and motors about equal-----	. 90
Predominantly motors with some lighting-----	. 85
Motors-----	. 80

(without reduction as in the case of generators). In selecting and locating transformers for lighting loads in military housing areas, a frequently used combination is 10 kv.-a. transformer distributing through three No. 6 conductors carrying single-phase 120/240 volt current.

d. Line Location. Normally electric distribution systems are of the radial type; lines radiate from generators or substations toward loads, branching and rebranching until all areas are served. The alternative is the ring type system in which the main distribution line forms a closed loop. The ring type normally distributes with less voltage drop but requires more time and material to construct. Lines are normally overhead. Lines carrying voltages above 240 are supported on poles (TM 5-680C); those carrying 120-240 volts are supported on poles or on masts or insulators attached to buildings.

125. Selecting Wire Sizes

a. Requirements. Electric conductors must be large enough to carry the current without heating unduly and without excessive voltage drop. Except for very short lines, the latter requirement is usually the controlling one.

b. Current-Carrying Capacity. Table 99 gives data on current capacities, based on room temperatures of 30° C. (86° F.). Table 100 gives correction factors for temperatures over 40° C. (104° F.). See also tables 101, 102, 103, and 104.

c. Voltage drop.

- (1) *Allowable drop.* The voltage drop is the total loss of voltage from the generator (or transformer or substation at which voltage is controlled) to the lights or motors. Part of the drop occurs in the distribution system (mains), part in the wires from the service entrance to the panel board (feeders), and part in the wires from the panel board to the outlet (branches). Electric wiring and distribution systems are planned for a total drop not in excess of 8 percent for lighting and 5 percent for power. Distribution is shown in table 105.

- (2) *Drop in distribution lines.* Voltage drop is difficult to compute but is obtained accurately enough for wiring layouts from the charts in figures 53 through 57. A separate chart is given for each voltage and type of circuit normally used in military systems. The upper scales of load and percent drop are used for heavier loads; the lower scales for light loads. Although drawn for 60-cycle current at various wire spacings, the charts may be used safely for 50-cycle current at the same spacings. In addition to the line voltage drop, a drop of one volt is added for each standard step-down transformer which forms a part of any line between an initial known voltage and a final load.
- (3) *Voltage drop and wire sizes in branch circuits.* Table 106 gives the wire sizes required for 115-volt circuits of various lengths of run, based on a drop of not more than two volts between the panel board and the outlets.

Table 99. Allowance Current Carrying Capacities of Conductors in Amperes for Not More Than Three Conductors in Raceway or Cable (Based on Room Temperature of 30° C. 86° F.) (See table 100)

A	B (note 2)	C	D	E	F	G
Size AWG or MCM	Rubber types R, RW, RU, RUW (14-2) Type RIL- RW (see note 1) Thermoplastic types T, TW	Rubber type RH type RH-RW (see note 1) type RHW	Paper	Asbestos varnished- cambric types AVA, AVL	Impregnated asbestos types A1 (14-8) A1A	Asbestos types A (14-8), AA
			Thermoplastic asbestos type TA			
			Var-Cam type V			
			asbestos Var-Cam type AVB			
			MI cable			
14 -----	15	15	25	30	30	30
12 -----	20	20	30	35	40	40
10 -----	30	30	40	45	50	55
8 -----	40	45	50	60	65	70
6 -----	55	65	70	80	85	95
4 -----	70	85	90	105	115	120
3 -----	80	100	105	120	130	145
2 -----	95	115	120	135	145	165
1 -----	110	130	140	160	170	190
0 -----	125	150	155	190	200	225
00 -----	145	175	185	215	230	250
000 -----	165	200	210	245	265	285
0000 -----	195	230	235	275	310	340
250 -----	215	255	270	315	335	-----
300 -----	240	285	300	345	380	-----

See notes at end of table.

Table 99—Continued

A	B (note 2)	C	D	E	F	G
Size AWG or MCM	Rubber types R, RW, RU, RUW (14-2) Type RH- RW (see note 1) Thermoplastic types T, TW	Rubber type RH type RH-RW (see note 1) type RHW	Paper	Asbestos varnished- cambric types AVA, AVL	Impregnated asbestos types AI (14-8) AIA	Asbestos types A (14-8), AA
			Thermoplastic asbestos type TA			
			Var-Cam type V			
			asbestos Var-Cam type AVB			
			MI cable			
350----	260	310	325	390	420	-----
400----	280	335	360	420	450	-----
500----	320	380	405	470	500	-----
600----	355	420	455	525	545	-----
700----	385	460	490	560	600	-----
750----	400	475	500	580	620	-----
800----	410	490	515	600	640	-----
900----	435	520	555	-----	-----	-----
1000----	455	545	585	680	730	-----
1250----	495	590	645	-----	-----	-----
1500----	520	625	700	785	-----	-----
1750----	545	650	735	-----	-----	-----
2000----	560	665	775	840	-----	-----

Note 1. If type RH-RW rubber-insulated wire is used in wet locations the allowable current carrying capacities will be that of column C, and if used in dry locations, the current carrying capacities will be that of column D.

Note 2. Insulation type and description.

Type	Description
R	code-grade rubber compound
RW	moisture-resistant rubber compound
RU	latex-rubber compound
RUW	latex-rubber, moisture-resistant compound
RH-RW	heat- and moisture-resistant rubber compound
RH	heat-resistant rubber compound
RHW	heat- and moisture-resistant compound
T	thermoplastic covered for dry locations
TA	thermoplastic and asbestos-covered for switchboard wiring
TW	thermoplastic-covered for moist locations
MI	mineral-insulated, copper-sheathed for general use and special high-temperature locations
A	non-impregnated, all-asbestos, w/o asbestos outer braid
AA	non-impregnated, all-asbestos, with asbestos outer braid
AI	impregnated, all-asbestos; w/o asbestos outer braid
AIA	impregnated, all-asbestos; with asbestos outer braid
AVA	impregnated-asbestos and varnished-cambric with asbestos braid
AVB	impregnated-asbestos and varnished-cambric, flame-resistant cotton braid
AVL	impregnated-asbestos and varnished-cambric, outer asbestos braid, lead sheathed
V	varnished-cambric

Table 100. Correction Factors for Various Room Temperatures Over 40° C. (104° F.)

° C.	° F.	B	C	D	E	F	G
40	104	0. 82	0. 88	0. 90	0. 94	0. 95	-----
45	113	. 71	. 82	. 85	. 90	. 92	-----
50	122	. 58	. 75	. 80	. 87	. 89	-----
55	131	. 41	. 67	. 74	. 83	. 86	-----
60	140	-----	. 58	. 67	. 79	. 83	0. 91
70	158	-----	. 35	. 52	. 71	. 76	. 87
75	167	-----	-----	. 43	. 66	. 72	. 86
80	176	-----	-----	. 30	. 61	. 69	. 84
90	194	-----	-----	-----	. 50	. 61	. 80
100	212	-----	-----	-----	-----	. 51	. 77
120	248	-----	-----	-----	-----	-----	. 69
140	284	-----	-----	-----	-----	-----	. 59

Note. Columns B to G refer back to table 99.

Table 101. Allowable Current-Carrying Capacities of Insulated Copper Conductors in Amperes

(Not more than three conductors in raceway or cable or direct burial (based on room temperature of 30° C. 86° F.))

Size AWG MCM	Rubber type R type RW	Rubber type RH	Paper	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA
	type RU type RUW (14-2)		thermo- plastic asbestos type TA			
	type RII-RW see note 4a	RUH (14-2)	Var-Cam type V			
	thermo- plastic	type RII-RW see note 4a	asbestos Var-Cam AVB			
	type T type TW	type RHW	MI cable			
			RIIII (°)			
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	-----
300	240	285	300	345	380	-----
350	260	310	325	390	420	-----
400	280	335	360	420	450	-----

See footnotes at end of table.

Table 101. Allowable Current-Carrying Capacities of Insulated Copper Conductors in Amperes—Continued

Size AWG MCM	Rubber type R type RW	Rubber type RHH (14-2) type RHH-RW see note 4a type RHHW	Paper	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA
	type RU type RUW (14-2)		thermo- plastic asbestos type TA			
	type RHH-RW see note 4a		Var-Cam type V			
	thermo- plastic		asbestos Var-Cam			
	type T type TW		AVB			
			MI cable RHH (1)			
500	320	380	405	470	500	-----
600	355	420	455	525	545	-----
700	385	460	490	560	600	-----
750	400	475	500	580	620	-----
800	410	490	515	600	640	-----
900	435	520	555	-----	-----	-----
1,000	455	545	585	680	730	-----
1,250	495	590	645	-----	-----	-----
1,500	520	625	700	785	-----	-----
1,750	545	650	735	-----	-----	-----
2,000	560	665	775	840	-----	-----

Correction Factors, Room Temperatures over 30° C. 86° F.

° C.	° F.						
40	104	0.82	0.88	0.90	0.94	0.95	-----
45	113	.71	.82	.85	.90	.92	-----
50	122	.58	.75	.80	.87	.89	-----
55	131	.41	.67	.74	.83	.86	-----
60	140	-----	.58	.67	.79	.83	0.91
70	158	-----	.35	.52	.71	.76	.87
75	167	-----	-----	.43	.66	.72	.86
80	176	-----	-----	.30	.61	.69	.84
90	194	-----	-----	-----	.50	.61	.80
100	212	-----	-----	-----	-----	.51	.77
120	248	-----	-----	-----	-----	-----	.69
140	284	-----	-----	-----	-----	-----	.59

See notes, following table 104.

ⁱ The current-carrying capacities for type RHH conductors for sizes AWG 14, 12, and 10 shall be the same as designated for type RII conductors in this table.

Table 102. Allowable Current-Carrying Capacities of Insulated Copper Conductors in Amperes

Single Conductor in Free Air

(Based on room temperature of 30° C. 86° F.)

Size AWG MCM	Rubber type R type RW	Rubber type RII	Thermo- plastic asbestos type TA	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA	Slow- burning type SB
	type RU type RUW (14-2)	RUII (14-2)	Var-Cam type V				weather- proof type WP
	type RH-RW see note 4a	type RH-RW see note 4a	asbestos Var-Cam type AVB				
	thermo- plastic type T type TW	type RIIW	MI cable RIII (1)				
14	20	20	30	40	40	45	30
12	25	25	40	50	50	55	40
10	40	40	55	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	-----	410
300	375	445	480	555	590	-----	460
350	420	505	530	610	655	-----	510
400	455	545	575	665	710	-----	555
500	515	620	660	765	815	-----	630
600	575	690	740	855	910	-----	710
700	630	755	815	940	1,005	-----	780
750	655	785	845	980	1,045	-----	810
800	680	815	880	1,020	1,085	-----	845
900	730	870	940	-----	-----	-----	905
1,000	780	935	1,000	1,165	1,240	-----	965
1,250	890	1,065	1,130	-----	-----	-----	-----
1,500	980	1,175	1,260	1,450	-----	-----	1,215
1,750	1,070	1,280	1,370	-----	-----	-----	-----
2,000	1,155	1,385	1,470	1,715	-----	-----	1,405

See footnotes at end of table.

Table 102. Allowable Current-Carrying Capacities of insulated Copper Conductors in Amperes—Continued

Correction Factors, Room Temperatures over 30° C. 86° F.

Size AWG MCM	Rubber type R type RW		Rubber type RH	Thermo- plastic asbestos type TA	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA	Slow- burning type SB
	type RU type RUW (14-2)		RUH (14-2)	Var-Cam type V				weather- proof type WP
	type RH-RW see note 4a		type RH-RW see note 4a	asbestos Var-Cam type AVB				
	thermo- plastic type T type TW		type RHW	MI cable RIIH (1)				
° C.	° F.							
40	104	0. 82	0. 88	0. 90	0. 94	0. 95	-----	-----
45	113	. 71	. 82	. 85	. 90	. 92	-----	-----
50	122	. 58	. 75	. 80	. 87	. 89	-----	-----
55	131	. 41	. 67	. 74	. 83	. 86	-----	-----
60	140	-----	. 58	. 67	. 79	. 83	. 91	-----
70	158	-----	. 35	. 52	. 71	. 76	. 87	-----
75	167	-----	-----	. 43	. 66	. 72	. 86	-----
80	176	-----	-----	. 30	. 61	. 69	. 84	-----
90	194	-----	-----	-----	. 50	. 61	. 80	-----
100	212	-----	-----	-----	-----	. 51	. 77	-----
120	248	-----	-----	-----	-----	-----	. 69	-----
140	284	-----	-----	-----	-----	-----	. 59	-----

See notes, following table 104.

¹ The current-carrying capacities for type RHH conductors for sizes AWG 14, 12, and 10 shall be the same as designated for type RII conductors in this table.

Table 103. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes

(Not More than Three Conductors in Raceway or Cable or Direct Burial (Based on room temperature of 30° C. 86° F.))

Size AWG MCM	Rubber type R, RW, RU, RUW (12-2)	Rubber type RH	Thermo- plastic asbestos type TA	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA
	type RH-RW note 4a	RUH (14-2)	Var-Cam type V			
		type RH-RW note 4a	asbestos Var-Cam type AVB			
	thermo- plastic type T, TW	type RHW	MI cable			
			RHH ¹			
12	15	15	25	25	30	30
10	25	25	30	35	40	45
8	30	40	40	45	50	55
6	40	50	55	60	65	75
4	55	65	70	80	90	95
3	65	75	80	95	100	115
*2	75	90	95	105	115	130
*1	85	100	110	125	135	150
*0	100	120	125	150	160	180
	115	135	145	170	180	200
*000	130	155	165	195	210	225
*0000	155	180	185	215	245	270
250	170	205	215	250	270	-----
300	190	230	240	275	305	-----
350	210	250	260	310	335	-----
400	225	270	290	335	360	-----
500	260	310	330	380	405	-----
600	285	340	370	425	440	-----
700	310	375	395	455	485	-----
750	320	385	405	470	500	-----
800	330	395	415	485	520	-----
900	355	425	455	-----	-----	-----
1, 000	375	445	480	560	600	-----
1, 250	405	485	530	-----	-----	-----
1, 500	435	520	580	650	-----	-----
1, 750	455	545	615	-----	-----	-----
2, 000	470	560	650	705	-----	-----

See footnotes at end of table.

Table 103. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes—Continued

Correction Factors, Room Temperatures over 30° C. 86° F.

Size AWG MCM	Rubber type R, RW, RU, RUW (12-2)	Rubber type RH (14-2)	Thermo- plastic asbestos type TA	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA
	type RH-RW note 4a	type RH-RW note 4a	Var-Cam type V			
	thermo- plastic type T, TW	type RHW	asbestos Var-Cam type AVB			
			MI cable			
			RHH ¹			
° C. ° F.						
40 104	0.82	0.88	0.90	0.94	0.95	-----
45 113	.71	.82	.85	.90	.92	-----
50 122	.58	.75	.80	.87	.89	-----
55 131	.41	.67	.74	.83	.86	-----
60 140	-----	.58	.67	.79	.83	0.91
70 158	-----	.35	.52	.71	.76	.87
75 167	-----	-----	.43	.66	.72	.86
80 176	-----	-----	.30	.61	.69	.84
90 194	-----	-----	-----	.50	.61	.80
100 212	-----	-----	-----	-----	.51	.77
120 248	-----	-----	-----	-----	-----	.69
140 284	-----	-----	-----	-----	-----	.59

See notes, following table 104.

*For three wire, single phase service and sub-service circuits, the allowable current-carrying capacity of RH, RH-RW, RHH and RHW aluminum conductors shall be for sizes #2-100 amp., #1-110 amp., #1/0-125 amp., #2/0-150 amp., #3/0-170 amp., and #4/0-200 amp.

¹ The current-carrying capacities for type RHH conductors for sizes AWG 12, 10, and 8 shall be the same as designated for type RH conductors in this table.

Table 104. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes

Single Conductor in Free Air (Based on room temperature of 30° C. 86° F.)

Size AWG MCM	Rubber type R, RW, RU, RUW (12-2)	Rubber type RM	Thermo- plastic asbestos type TA	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA	Slow- burning type SB
	type RH-RW note 4a	RUH (14-2)	Var-Cam type V				Weather- proof type WP
	thermo- plastic type T, TW	type RH-RW Note 4a	asbestos Var-Cam type AVB				
		type RHW	MI cable RHH :				
12	20	20	30	40	40	45	30
10	30	30	45	50	55	60	45
8	45	55	55	65	70	80	55
6	60	75	80	95	100	105	80
4	80	100	105	125	135	140	100
3	95	115	120	140	150	165	115
2	110	135	140	165	175	185	135
1	130	155	165	190	205	220	160
0	150	180	190	220	240	255	185
00	175	210	220	255	275	290	215
000	200	240	255	300	320	335	250
0000	230	280	300	345	370	400	290
250	265	315	330	385	415	-----	320
300	290	350	375	435	460	-----	360
350	330	395	415	475	510	-----	400
400	355	425	450	520	555	-----	435
500	405	485	515	595	635	-----	490
600	455	545	585	675	720	-----	560
700	500	595	645	745	795	-----	615
750	515	620	670	775	825	-----	640
800	535	645	695	805	855	-----	670
900	580	700	750	-----	-----	-----	725
1000	625	750	800	930	990	-----	770
1250	710	855	905	-----	-----	-----	-----
1500	795	950	1, 020	1, 175	-----	-----	985
1750	875	1, 050	1, 125	-----	-----	-----	-----
2000	960	1, 150	1, 220	1, 425	-----	-----	1, 165

See footnotes at end of table.

Table 104. Allowable Current-Carrying Capacities of Insulated Aluminum Conductors in Amperes—Continued

Correction Factors, Room Temperatures over 30° C. 86° F.

Size AWG MCM	Rubber type R, RW, RU, RUW (12-2)	Rubber type RM	Thermo- plastic asbestos type TA	Asbestos Var-Cam type AVA type AVL	Impreg- nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA	Slow- burning type SB
	type RH-RW note 4A	RUH (14-2)	Var-Cam type V				Weather- proof type WP
	thermo- plastic type T, TW	type RH-RW Note 4a	asbestos Var-Cam type AVB				
		type RHW	MI cable RHH ¹				
°C. °F.							
40 104	0.82	0.88	0.90	0.94	0.95	-----	-----
45 113	.71	.82	.85	.90	.92	-----	-----
50 122	.58	.75	.80	.87	.89	-----	-----
55 131	.41	.67	.74	.83	.86	-----	-----
60 140	-----	.58	.67	.79	.83	0.91	-----
70 158	-----	.35	.52	.71	.76	.87	-----
75 167	-----	-----	.43	.66	.72	.86	-----
80 176	-----	-----	.30	.61	.69	.84	-----
90 194	-----	-----	-----	.50	.61	.80	-----
100 212	-----	-----	-----	-----	.51	.77	-----
120 248	-----	-----	-----	-----	-----	.69	-----
140 284	-----	-----	-----	-----	-----	.59	-----

See notes following table 104.

¹ The current-carrying capacities for type RHH conductors for sizes AWG 12, 10, and 8 shall be the same as designated for type RII conductors in this table.

Notes to Tables 101–104

(Section references are to the National Electrical Code of 1956)

1. *Aluminum conductors.* For aluminum conductors, the allowable current-carrying capacities shall be in accordance with tables 103 and 104.

2. *Bare conductors.* If bare conductors are used with insulated conductors, their allowable current-carrying capacity shall be limited to that permitted for the insulated conductors of the same size.

3. *Application of table.* For open wiring on insulators and for concealed knob-and-tube work, the allowable current-carrying capacities of tables 102 and 104 shall be used. For all other recognized wiring methods, the allowable current-carrying capacities of tables 101 and 103 shall be used, unless otherwise provided in this code.

The temperature limitation on which the current-carrying capacities of type MI cable are based, is determined by the insulating materials used in the end seal. Termination fittings incorporating unimpregnated organic insulating materials are limited to 85° C. operation.

4. *More than three conductors in a raceway.* Tables 101 and 103 give the allowable current-carrying capacity for not more than three conductors in a raceway or cable. If the number of conductors in a raceway or cable is from 4 to 6 the allowable current-carrying capacity of each conductor shall be reduced to 80 percent of the values in tables 101 and 103. If the number of conductors in a raceway or cable is from 7 to 9, the allowable current-carrying capacity of each conductor shall be reduced to 70 percent of the values in tables 101 and 103. (Exceptions to the foregoing are specified in sections 3624, 3745, and 7265.)

4. a. If type RH–RW rubber insulated wire is used in wet locations the allowable current-carrying capacities shall be that of Column 2 in tables 101 to 104. If used in dry locations the allowable current-carrying capacities shall be that of column 3 in tables 101 to 104.

5. *Neutral conductor.* A neutral conductor which carries only the unbalanced current from other conductors, as in the case of normally balanced circuits of three or more conductors, shall not be counted in determining current-carrying capacities as provided for in the preceding paragraph.

(In a 3-wire circuit consisting of two phase wires and the neutral of a 4-wire, 3-phase system, a common conductor carries approximately the same current as the other conductors and is not therefore considered as a neutral conductor.)

6. *Ultimate insulation temperature.* In no case shall conductors be associated together in such a way with respect to the kind of circuit, the wiring method employed, or the number of conductors, that the limiting temperature of the conductors will be exceeded.

7. *Use of conductors with higher operating temperatures.* If the room temperature is within 10° C. of the maximum allowable operating temperature of the insulation, it is desirable to use an insulation with a higher maximum allowable operating temperature; although insulation can be used in a room temperature approaching its maximum allowable operating temperature limit if the current is reduced in accordance with the table of correction factors for different room temperatures.

8. *Voltage drop.* The allowable current-carrying capacities in tables 101 to 104 are based on temperature alone and do not take voltage drop into consideration.

9. *Overcurrent protection.* If the standard ratings and settings of overcurrent devices do not correspond with the ratings and settings allowed for conductors, the next higher standard rating and setting may be used, but not exceeding 150 percent of the allowable carrying capacity of the conductor.

10. *Deterioration of insulation.* It should be noted that even the best grades of rubber insulation will deteriorate in time, so eventually will need to be replaced.

Table 105. Voltage Drop, Distribution Systems

Circuits	System voltage					
	110	115	220	230	440	550
	Voltage drop in volts					
Lighting:						
Branches.....	4.4	4.6	8.8	9.2	-----	-----
Mains and feeders, combined.....	4.4	4.6	8.8	9.2	-----	-----
Total.....	8.8	9.2	17.6	18.4	-----	-----
Power:						
Branches.....	2.2	2.3	2.2	2.3	4.4	5.5
Mains and feeders, combined.....	3.3	3.5	8.8	9.2	17.6	22.0
Total.....	5.5	5.8	11.0	11.5	22.0	27.5

- (4) A nomograph for finding voltage drop (approximately) is given in figure 58. Example: to find the size of wire to carry 10 amperes 100 feet with a 2-volt drop of potential; place a straightedge on 2 volts and 10 amperes, read .2 ohm at the intersection of the straightedge with the ohms scale; place the straightedge on .2 ohm and 100 feet, read No. 10 gage at the intersection of the straightedge with the A.W.G. scale.

126. Typical Electrical Layout for Hospital

A typical electrical distribution layout for a 500-bed hospital, Standard 3, is shown on figure 59. The load centers are each equipped with two 60-KW, 3 ϕ , 4W 120-208V generators.

127. Pole Lines

a. General. See TM 5-765 for construction details of overhead distribution systems. In general, pole lines should be installed along streets or roads, wherever practicable, in order to avoid the need for separate poles for street lights. In connection with the selection of pole lengths, allowance should be made for the installation of telephone lines on all distribution poles. These lines are usually installed by the Signal Corps or the local telephone company, but the designer of the distribution system is responsible for the additional space and strength requirements. Specified pole lengths include the section below ground line.

b. Depth. Table 107 gives the depths to which poles of various lengths should be set in soil and in rock. Table 108 gives similar data for the case of rock overlaid with a thin layer of soil.

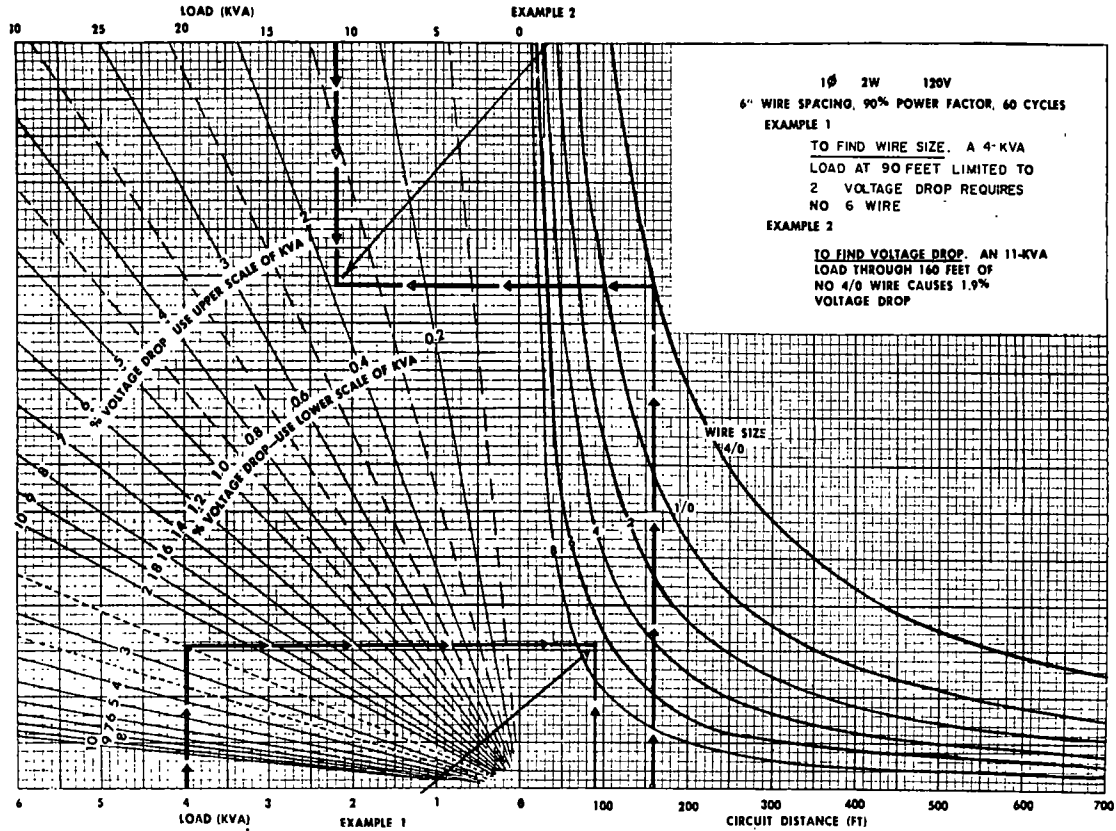


Figure 53. Voltage-drop and wire-size chart for single-phase two-wire 120-volt circuits.

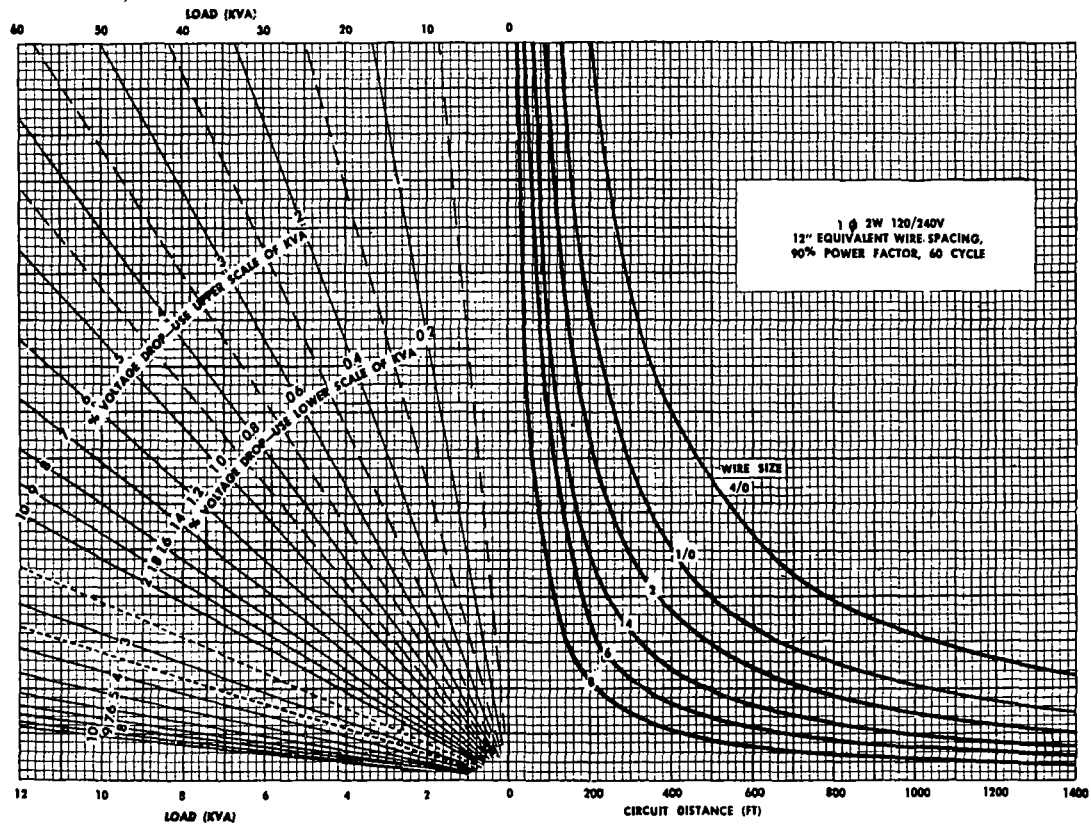


Figure 54. Voltage-drop and wire-size chart for single-phase three-wire 120/240 volt circuits.

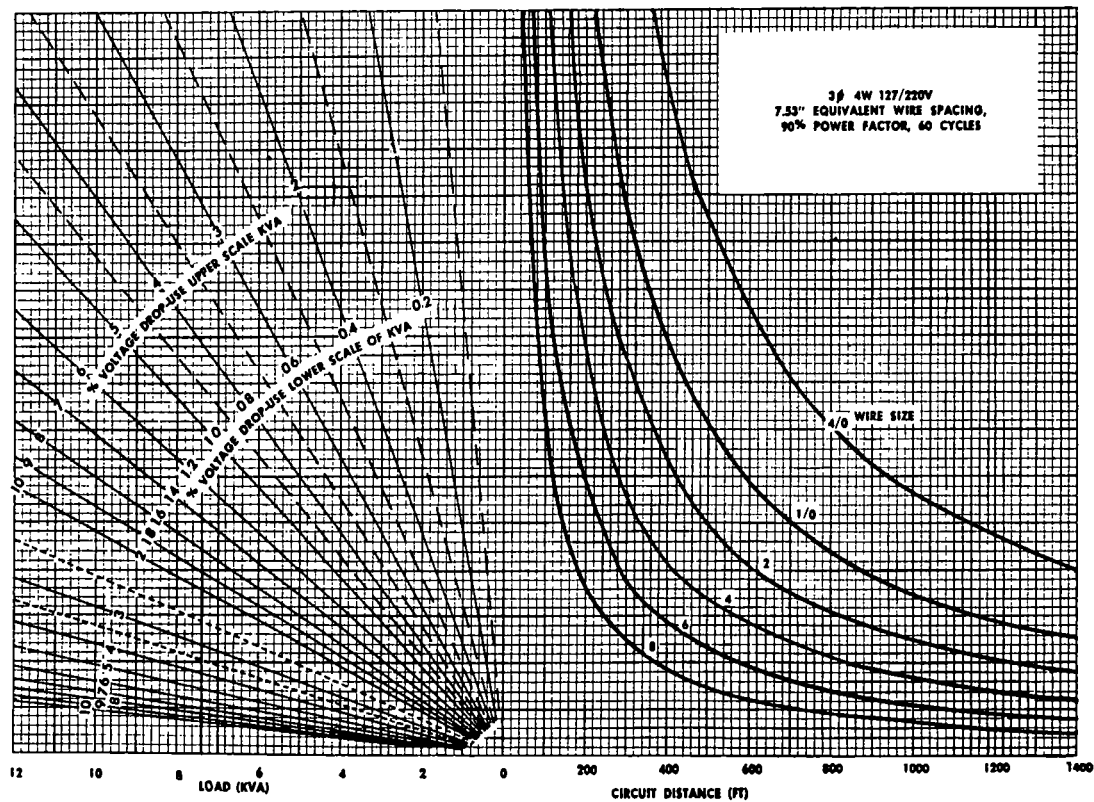


Figure 55. Voltage-drop and wire-size chart for three-phase four-wire 127/220 volt circuits.

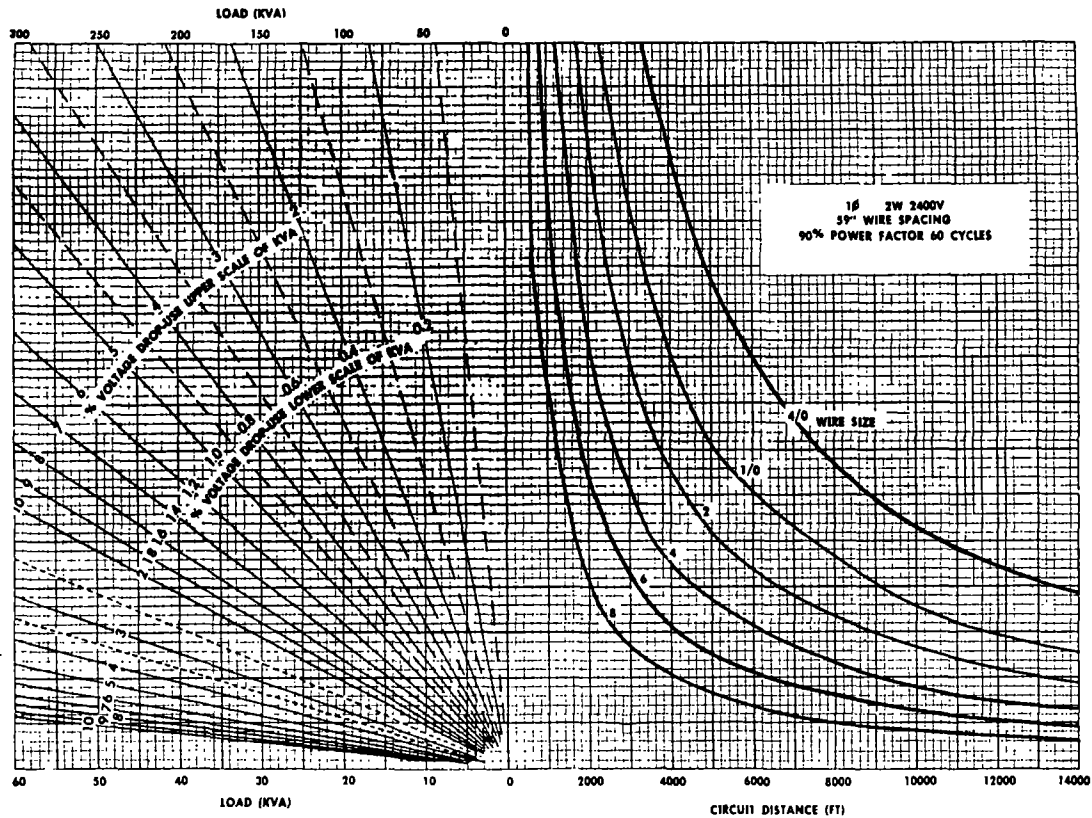


Figure 56. Voltage-drop and wire-size chart for single-phase two-wire 2,400-volt circuits.

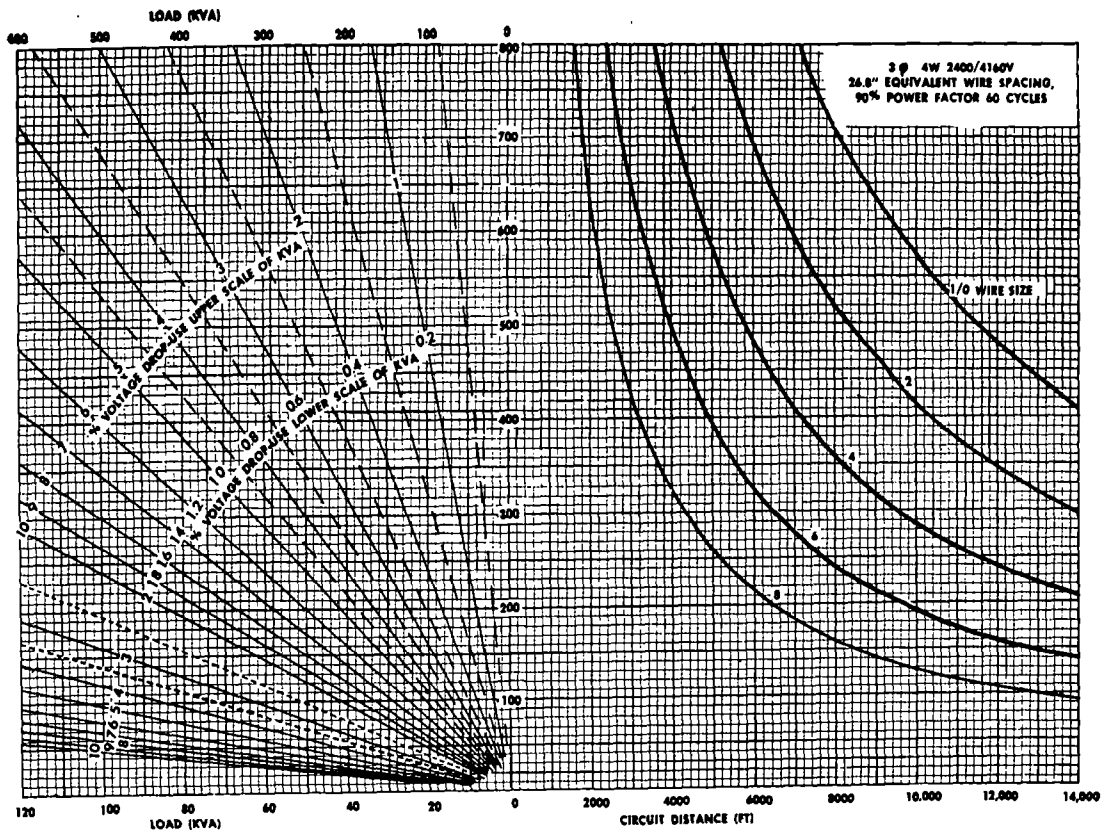
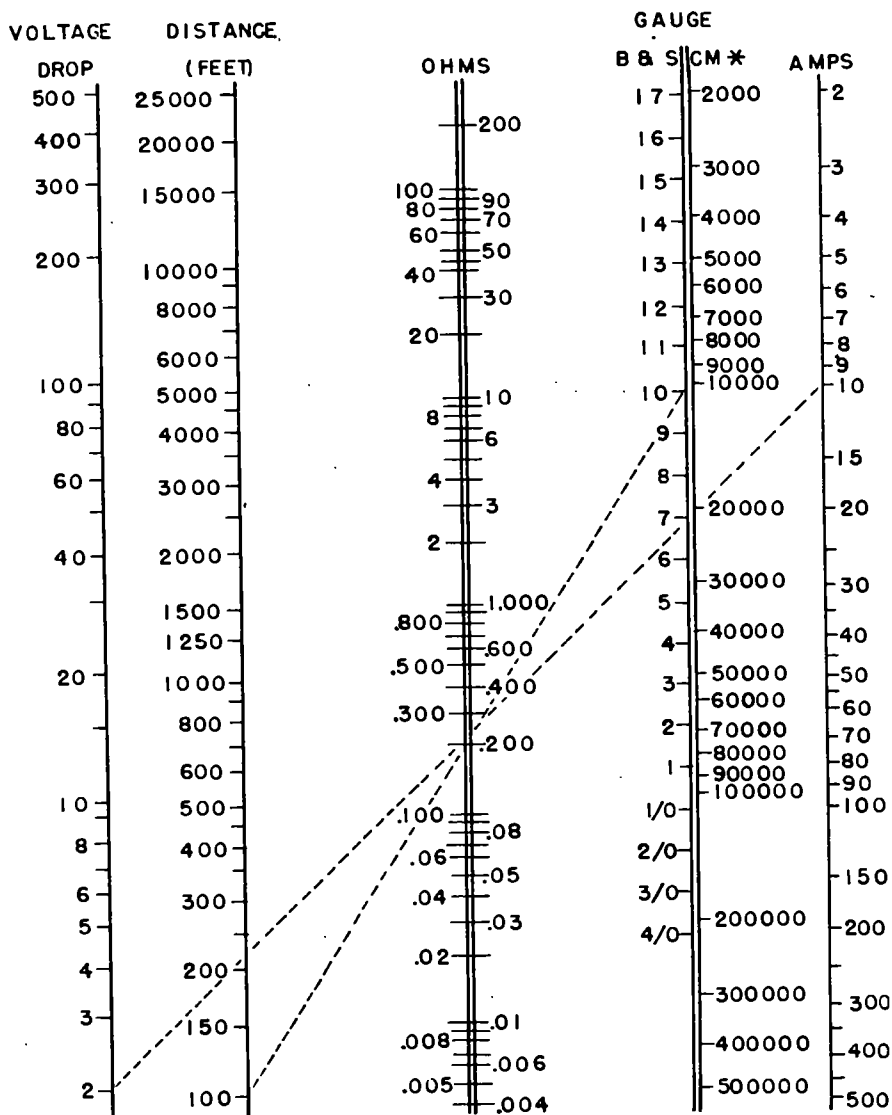


Figure 57. Voltage-drop and wire-size chart for three-phase four-wire 2,400/4,160-volt circuits.

Table 106. Watts per Circuit

Length of run in feet (panel box to outlet)	100	150	200	300	400	500	600	700	800	900	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
30.....	14	14	14	14	14	14	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10	10
40.....	14	14	14	14	14	14	14	14	14	14	14	12	12	12	10	10	10	10	10	8	8	8
50.....	14	14	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10	8	8	8	8	8
60.....	14	14	14	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	8	6	6
70.....	14	14	14	14	14	14	14	12	12	12	12	10	10	8	8	8	8	8	6	6	6	6
80.....	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	8	6	6	6	6	6
90.....	14	14	14	14	14	12	12	12	10	10	10	10	8	8	8	6	6	6	6	6	6	4
100.....	14	14	14	14	14	12	12	12	10	10	10	8	8	8	6	6	6	6	6	6	4	4
110.....	14	14	14	14	14	12	12	10	10	10	10	8	8	8	6	6	6	6	6	4	4	4
120.....	14	14	14	14	12	12	10	10	10	10	8	8	8	6	6	6	6	4	4	4	4	4
130.....	14	14	14	14	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4	4	4	4
140.....	14	14	14	14	12	12	10	10	8	8	8	8	6	6	6	6	4	4	4	4	4	4
150.....	14	14	14	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4	4	4	4	2
160.....	14	14	14	12	12	10	10	8	8	8	8	6	6	6	4	4	4	4	4	4	2	2
170.....	14	14	14	12	12	10	10	8	8	8	8	6	6	6	4	4	4	4	4	2	2	2
180.....	14	14	14	12	10	10	10	8	8	8	6	6	6	4	4	4	4	4	2	2	2	2
190.....	14	14	14	12	10	10	8	8	8	8	6	6	4	4	4	4	4	4	2	2	2	2
200.....	14	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	4	2	2	2	2	2
210.....	14	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2	2	2
220.....	14	14	14	12	10	10	8	8	8	6	6	6	4	4	4	2	2	2	2	2	2	2
230.....	14	14	12	12	10	8	8	8	6	6	6	6	4	4	4	2	2	2	2	2	2	1
240.....	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2	2	1	1
250.....	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2	2	1	1



$$* \text{ CIRCULAR MILS} = \frac{\text{AMPERES} \times \text{DISTANCE IN FEET} \times 21.6}{\text{VOLTAGE DROP}}$$

Figure 58. Wire sizes and voltage drops.

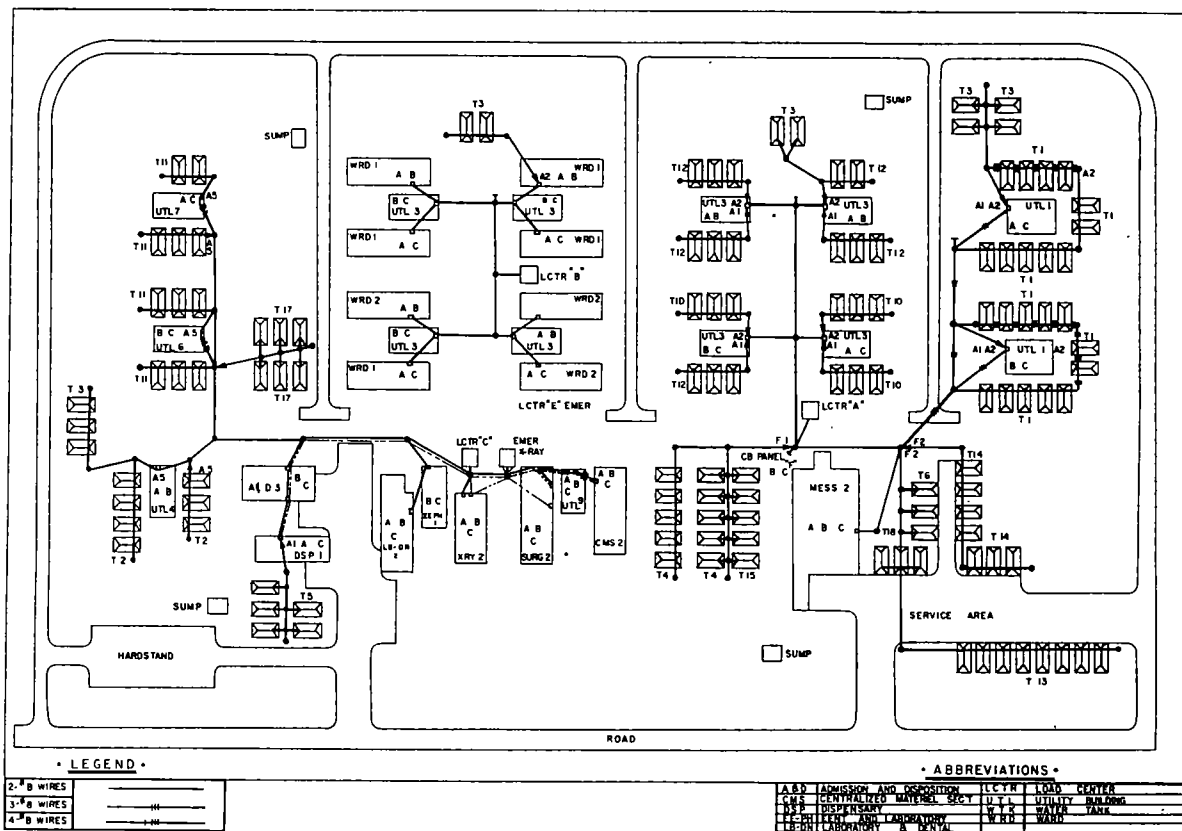


Figure 59. Typical electrical distribution system in a 500-bed hospital, Standard 3.

Table 107. Depth for Setting Pole in Soil or Rock

Height of pole (feet)	Depth of setting (feet)	
	In soil	In rock
20-----	5	3
25-----	5½	3½
30-----	5½	4
35-----	6	4
40-----	6	4
45-----	6½	4½
50-----	7	4½
55-----	7½	5
60-----	8	5

Table 108. Division of Setting Depth in Feet Between Soil and Rock

30-foot pole		40-foot pole		50-foot pole		60-foot pole	
Soil	Rock	Soil	Rock	Soil	Rock	Soil	Rock
0-----	4	0	4	0	4½	0	5
1-----	4	1	4	1	4½	1	5
2-----	3	2	3	2	4	2	4½
3-----	2	3	2	3	3	3	4
4-----	1½	4	1½	4	2½	4	3
-----	-----	5	1	5	2	5	2
-----	-----	-----	-----	6	1	6	1½
-----	-----	-----	-----	-----	-----	7	1

c. Strength. The class of pole is determined on the basis of its ultimate breaking strength at the ground line as listed in table 109. Poles should have four times the strength required to support the actual vertical and transverse loading, except when the poles are guyed. The guy should support the entire load in the direction in which it acts, the pole simply acting as a strut. See *l* below for characteristics of guys.

Table 109. Breaking Strength of Classified Poles

Class	Load, pound force	Class	Load, pound force
1-----	4,500.	5-----	1,900.
2-----	3,700.	6-----	1,500.
3-----	3,000.	7-----	1,200.
4-----	2,400.	8 to 10-----	Not specified.

d. Footings. Foundations for vertical loads, including the vertical components of guys, must be adequate to prevent the pole from sinking into the ground. When the area of the butt of a pole is too small to bear the vertical load without sinking, a pole footing of planks or concrete is installed under the butt. Existing poles need not be reinforced unless observed to be sinking. The alignment chart in figure 60 is used to determine adequate support for vertical loads in various types of soil. The pole circumference at the ground line is used as a measure of bearing area. For example, as shown by the dotted line in the alignment chart, a pole bearing a vertical load of 8,000 pounds in sandy soil requires a pole footing with a ground-line circumference of 45 inches. If the class of pole in use or available for use has a circumference smaller than 45 inches, a pole footing similar to that illustrated should be used to provide the necessary bearing area. By laying a straightedge across the alignment chart a third condition can be determined if any two are known.

e. Pole spacing. Poles are spaced at about 125 feet in a straight pole line. The usual maximum is 150 feet; the minimum about 100 feet. In curves and at corners the spacing is reduced as shown in figure 61. For rural lines (relatively long lines and light loads) spans up to 200 or 250 feet are used; and up to 400 or 500 feet when steel-reinforced aluminum cable is used.

f. Wire spacing. Three- and four-wire circuits are normally carried on poles without crossarms, using strain type insulator elevises spaced as shown in figure 62.

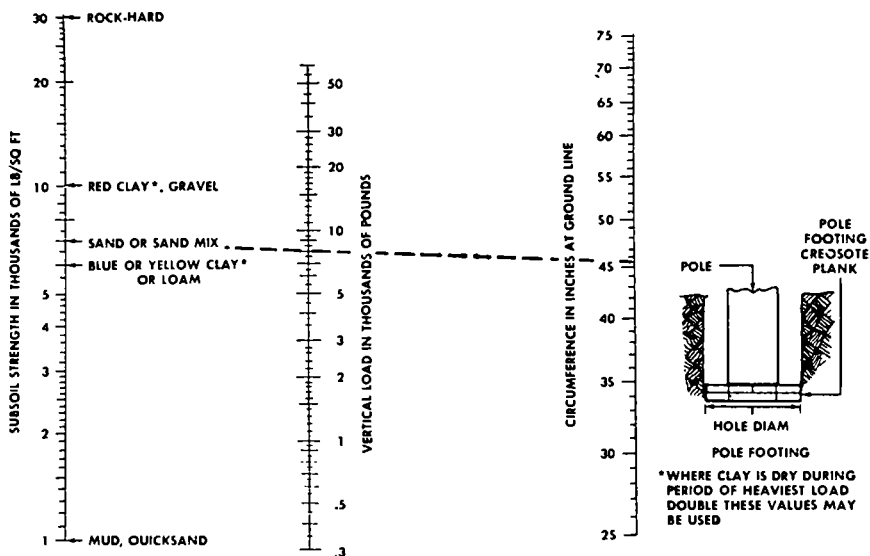
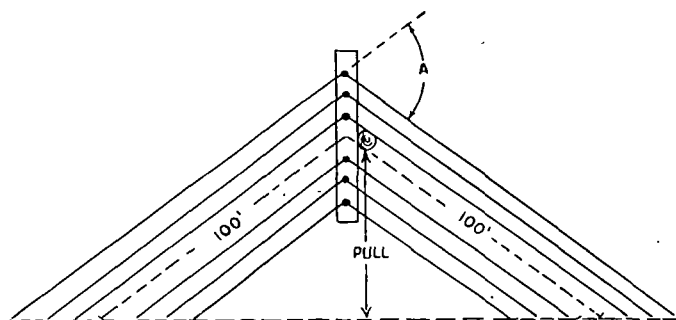


Figure 60. Alignment chart for pole or pole-footing diameters.



NOTE. If the "PULL" is less than 5', the spans adjacent to the angle pole may be standard 125' length. If the "PULL" exceeds 5', the spans adjacent to the angle pole shall be reduced to the distance given in the table.

ANGLE A	PULL IN FEET	SPAN FEET	NO OF 6000 # SIDE GUYS		
			1 ARM 6 WIRES	2 ARMS 12 WIRES	3 ARMS 18 WIRES
Less Than 6°	Less Than 5'	125	None	None	None
6° - 11°	5' - 10'	115	None	1	1
11° - 15°	10' - 13'	105	1	1	1
15° - 22°	13' - 19'	95	1	1	2
22° - 30°	19' - 26'	85	1	1	2
Over 30°	Over 26'	75	1	2	2

Figure 61. Pole spacing and side guys on curves.

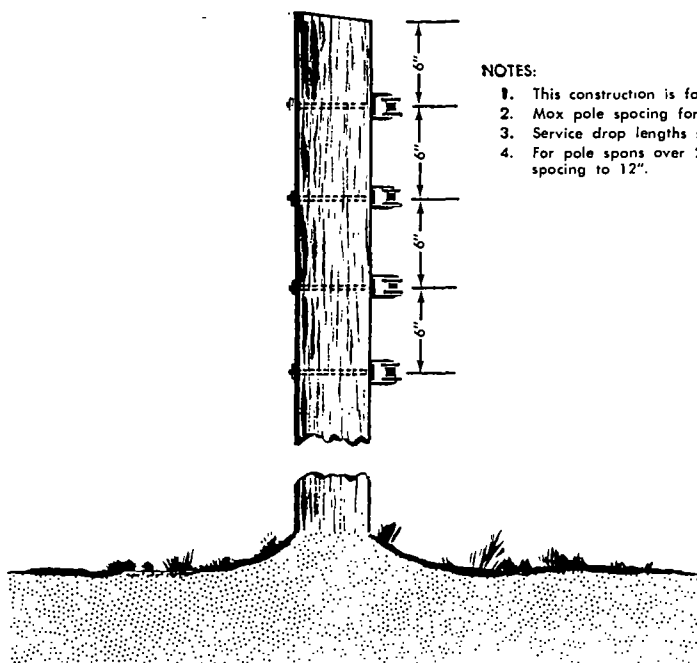
g. Wire clearances aboveground. Minimum allowable clearances under various conditions are given in figure 63.

h. Wire. Diameters, weights, and resistances of wires normally used in overhead distribution systems are given in tables 110 through 114.

i. Sag. Sags in inches for various wire sizes, stringing temperatures, and span lengths, based on hard- and medium-drawn insulated copper wire, are shown in table 115.

j. Tension. The tension in an overhead wire, in parts of the weight of the wire span including any insulation and ice coating, and for various sag ratios is shown in table 116. The table also gives the vertical angle at which the wire leaves the pole, for plotting the vertical and horizontal components of the tension.

k. Loads and ultimate strengths of wire. See TM 5-765 for more complete data on loadings. The National Electrical Safety Code divides the United States into three zones classed as heavy, medium, and light loading areas, respectively, based on the ice and wind loads to be expected on overhead lines. (See figure 64.) The wind loads vary from 4 to 9 pounds per square foot, and the radial thickness of



NOTES:

1. This construction is for No. 8 wire or larger.
2. Max pole spacing for No. 8 wire, is 150'.
3. Service drop lengths should not exceed 100'.
4. For pole spans over 200', increase wire spacing to 12".

Figure 62. Wire spacing on poles.

ice on conductors is one-half inch in the heavy zone (coupled with a temperature of 0° F.), one-fourth inch in the medium zone (at plus 15° F.) and none in the light zone. Tables 117 to 121 give the loading per foot of conductor for the three loading areas and strength data for conductors ordinarily used at Army installations. The allowable tension is usually taken as one-half the ultimate strength given in the tables.

Table 110. Bare Solid Copper Wire

Size (AWG)	Diameter (inches)	Weight (pounds per 1,000 feet)	Resistance (ohms per 1,000 feet at 20° C.)
4/0-----	0. 4600	639. 8	0. 04893
3/0-----	. 4096	507. 3	. 06170
2/0-----	. 3648	402. 4	. 07780
1/0-----	. 3250	319. 4	. 09811
1-----	. 2893	253. 0	. 1237
2-----	. 2576	200. 6	. 1560
3-----	. 2294	159. 1	. 1967
4-----	. 2043	126. 2	. 2480
5-----	. 1819	100. 0	. 3128
6-----	. 1620	79. 35	. 3944
7-----	. 1443	62. 96	. 4973
8-----	. 1285	49. 92	. 6271

Table 112. Bare Stranded Copper Wire

Size (AWG)	Diameter (inches)	Weight (pounds per 1,000 feet)	Resistance (ohms per 1,000 feet at 20° C.)	Wires in strand
4/0-----	0. 5275	653. 14	0. 04997	19
3/0-----	. 4644	412. 07	. 06293	7
2/0-----	. 4134	406. 98	. 07935	7
1/0-----	. 3684	322. 39	. 10007	7
1-----	. 3279	255. 45	. 12617	7
2-----	. 2919	202. 50	. 15725	7
3-----	. 2601	160. 60	. 19827	7
4-----	. 2316	127. 40	. 25000	7
6-----	. 1836	80. 10	. 39767	7

Table 113. Weatherproof Stranded Copper Wire

Size (AWG)	Diameter over insulation (inches)		Wires in strand	Weight (pounds per 1,000 feet)		Resistance (ohms per 1,000 feet at 20° C.)
	Three-braid	Two-braid		Three-braid	Two-braid	
4/0-----	0. 812	0. 687	19	800	745	0. 04997
3/0-----	. 734	. 671	7	653	604	. 06293
2/0-----	. 687	. 625	7	522	482	. 07935
1/0-----	. 640	. 578	7	424	388	. 10007
1-----	. 593	. 531	7	328	303	. 12617
2-----	. 531	. 468	7	270	246	. 15725
3-----	. 468	. 421	7	206	190	. 19827
4-----	. 437	. 390	7	. 70	155	. 25000
6-----	. 406	. 359	7	115	103	. 39767

Table 114. Bare Solid Steel Wire

Size (BWG)	Approximate diameter (inches)	Weight (pounds per 1,000 feet)	Current load (amperes)			
			1	2.5	5	10
			Resistance (ohms per mile at 20° C.)			
4-----	0. 238	154	7. 48	7. 59	7. 92	9. 23
6-----	. 203	112	10. 15	10. 42	10. 79	12. 47
8-----	. 165	73. 5	15. 06	15. 26	15. 71	18. 35

Table 115. Wire Sag in Inches

Wire size AWG	String- ing temp °F.	Frigid and Temp Zones							Tropical Zones						
		Spans							Spans						
		100'	125'	150'	175'	200'	250'	300'	100'	125'	150'	175'	200'	250'	300'
8----	30	15	23	36	-----	-----	-----	-----	8.5	14	22.5	31	-----	-----	---
	60	18	37	40	-----	-----	-----	-----	12	18	27	36	-----	-----	---
	90	21.5	31	44	-----	-----	-----	-----	15.5	22.5	32	41	-----	-----	---
6----	30	8.5	14	22	31	-----	-----	-----	6	9	14	19.5	26	-----	---
	60	12	18	27	36	-----	-----	-----	8	12	18	24	32	-----	---
	90	15.5	22.5	32	40	-----	-----	-----	11	16	22.5	29	38	-----	---
4----	30	8.5	14	21.5	31	43	-----	-----	6.5	9	14	19	26	-----	---
	60	12	18	27	36	48	-----	-----	8	12	18	24	32	-----	---
	90	17	22.5	32	41	54	-----	-----	11.5	16	22	30	38	-----	---
2----	30	8.5	14	21.5	23.5	30	53	89	6.5	9	14	17.5	21	28	45
	60	12	18	27	30	36	60	96	8	12	18	22	26	34	52
	90	17	22.5	32	35	42	67	103	11.5	16	22	27	32	41	60
1----	30	8.5	13.5	20.5	22.5	26	42	66	5.5	9	13.5	16.5	19	26	38
	60	12	18	26	28	32	49	72	8	12	18	21	24	31	45
	90	15.5	22.5	31	34	38	56	82	11.5	16	23	26	30	38	53
1/0---	30	8.5	13.5	20.5	22.5	26	42	66	5.5	9	14	16.5	18	24.5	34
	60	12	18	26	28	32	49	72	8	12	18	21	23	30	41
	90	15.5	22.5	31	34	38	56	82	11.5	16.5	23	27	28	36	47
2/0---	30	8.5	13.5	20	22.5	25	38	57	5.5	9	13.5	16	17.5	23	31
	60	12	18	25	28	31	46	66	8	12	18	20	22	28	37
	90	16	22.5	30	34	38	53	73	11.5	16	23	25	28	35	45
4/0---	30	8.5	13.5	18.5	21	24.5	31	43	5.5	8.5	13.5	16	16.5	20.5	27
	60	12	18	24	27	30	38	50	8	12	18	19	21	25	32
	90	16	22.5	29	33	36	46	59	11.5	16	23	24.5	26	31	39

l. Guys and guy loads. The ordinary guying of poles at bends in lines is covered in *e* above. For heavier loads, dead ends, corners, and the like, find the resultant horizontal load by a parallelogram of forces, determine the guy slope practicable, and select guys from figure 65.

m. Crossarms. See TM 5-765 for additional data. All crossarm loads are reduced to an equivalent load on the end pin, horizontally and vertically, and the horizontal unbalance is determined as shown in figure 66. The required crossarm size or any necessary doubling of crossarms is then selected from tables 122 and 123.

128. Wire Sizes

Tables 124, 125, and 126 are based upon a voltage drop of about 3 percent.

Table 116. Wire-Sag Tension

Sag in parts of the span	Sag in decimal parts of span	Tension at pole in parts of the weight of the span of wire	Vertical angle of wire leaving pole		Length of wire in parts of span
			Deg.	Min.	
1/300-----	0. 00333	37. 5	0	46	¹ 1. 00
1/200-----	. 005	25. 0	1	09	¹ 1. 00
1/150-----	. 0067	18. 8	1	32	¹ 1. 00
1/125-----	. 008	15. 6	1	50	¹ 1. 00
1/100-----	. 01	12. 5	2	18	¹ 1. 00
1/80-----	. 0125	10. 0	2	52	¹ 1. 00
1/67.5-----	. 015	8. 45	3	23	¹ 1. 00
1/50-----	. 02	6. 27	4	35	¹ 1. 00
1/40-----	. 025	5. 03	5	43	¹ 1. 00
1/35-----	. 0286	4. 40	6	31	¹ 1. 00
1/30-----	. 0333	3. 78	7	36	¹ 1. 00
1/25-----	. 04	3. 16	9	06	¹ 1. 00
1/20-----	. 05	2. 55	11	19	1. 01
1/15-----	. 0667	1. 94	14	55	1. 01
1/10-----	. 1	1. 35	21	48	1. 03
1/5-----	. 2	. 800	38	40	1. 10
1/4-----	. 25	. 707	45	00	1. 15
1/3-----	. 333	. 625	53	08	1. 25
1/2-----	. 5	. 559	63	26	1. 48

¹ Less than 1.005.

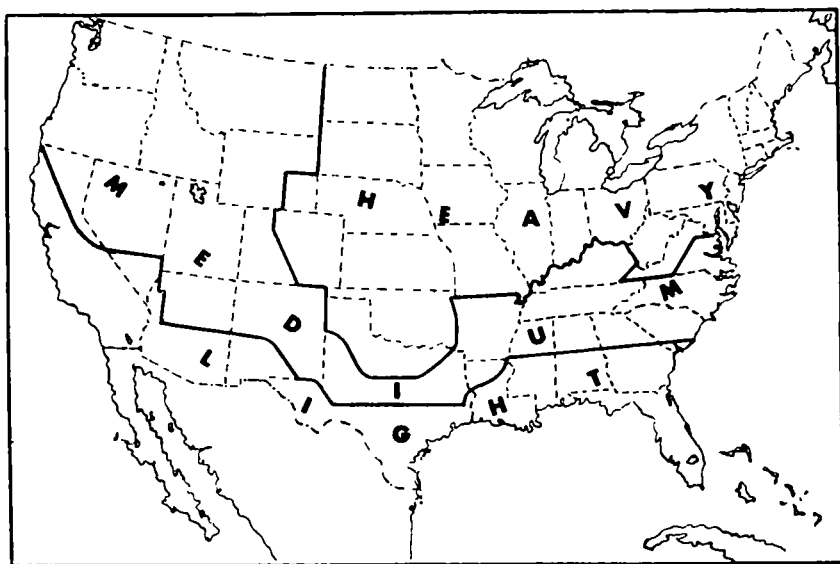


Figure 64. Loading map for overhead wires.

Table 117. Solid Copper, Triple-Braid, Weatherproof Wire

Conductor size AWG	Ultimate strength (pounds)			Loading (pounds per linear foot of conductor)								
	Hard drawn (minimum)	Medium hard drawn (minimum)	Annealed (maximum)	Light loading			Medium loading			Heavy loading		
				Vertical (conductor without ice)	Transverse (9- lb. wind per square foot on conductor without ice)	Conductor loading ¹	Vertical (conductor plus 1/4-in. radial ice)	Transverse (4- lb. wind per square foot on ice-covered conductor)	Conductor loading ¹	Vertical (conductor plus 1/2-in. radial ice)	Transverse (4- lb. wind per square foot on ice-covered conductor)	Conductor loading ¹
4/0-----	7, 740	6, 630	6, 280	0. 767	0. 578	1. 010	1. 084	0. 423	1. 384	1. 557	0. 590	1. 975
3/0-----	6, 390	5, 380	4, 980	. 629	. 533	. 875	. 927	. 403	1. 231	1. 381	. 570	1. 804
2/0-----	5, 240	4, 370	3, 950	. 502	. 473	. 740	. 776	. 377	1. 083	1. 205	. 543	1. 632
1/0-----	4, 290	3, 540	3, 130	. 407	. 428	. 641	. 662	. 357	. 972	1. 072	. 523	1. 503
1-----	3, 503	2, 870	2, 550	. 316	. 390	. 552	. 555	. 340	. 872	. 950	. 507	1. 387
2-----	2, 850	2, 330	2, 030	. 260	. 356	. 492	. 485	. 325	. 803	. 866	. 492	1. 306
3-----	2, 320	1, 885	1, 606	. 199	. 315	. 423	. 407	. 307	. 730	. 771	. 473	1. 215
4-----	1, 872	1, 505	1, 274	. 164	. 293	. 386	. 363	. 297	. 689	. 717	. 463	1. 164
6-----	1, 216	960	801	. 112	. 251	. 325	. 294	. 278	. 625	. 631	. 445	1. 082
8-----	785	612	504	. 075	. 218	. 281	. 243	. 263	. 578	. 566	. 430	1. 021
10-----	503	390	330	. 053	. 188	. 245	. 208	. 250	. 545	. 519	. 417	0. 976
12-----	402	249	207	. 035	. 158	. 212	. 178	. 237	. 516	. 476	. 403	0. 934

¹ Conductor loading per foot as specified in Rule 251, NESC, 5th edition.

Table 118. Stranded Copper, Triple-Braid, Weatherproof Wire

Conductor size circular mils or AWG	Ultimate strength (pounds)			Loading (pounds per linear foot of conductor)								
	Hard drawn (minimum)	Medium hard drawn (minimum)	Annealed (maximum)	Light loading			Medium loading			Heavy loading		
				Vertical (conductor without ice)	Transverse (9- lb. wind per square foot on conductor without ice)	Conductor loading ¹	Vertical (conductor plus ½-in. radial ice)	Transverse (4- lb. wind per square foot on ice-covered conductor)	Conductor loading ¹	Vertical (conductor plus ½-in. radial ice)	Transverse (4- lb. wind per square foot on ice-covered conductor)	Conductor loading ¹
1000000-----	41, 610	32, 630	30, 510	3. 670	1. 275	3. 935	4. 276	0. 733	4. 559	5. 038	0. 900	5. 429
750000-----	31, 730	24, 840	22, 880	2. 822	1. 125	3. 088	3. 366	. 667	3. 652	4. 066	. 833	4. 460
500000-----	21, 390	16, 450	15, 260	1. 894	. 938	2. 163	2. 361	. 583	2. 651	2. 983	. 750	3. 385
350000-----	14, 380	11, 590	10, 680	1. 345	. 788	1. 609	1. 749	. 517	2. 053	2. 309	. 683	2. 718
250000-----	10, 790	8, 394	7, 628	. 984	. 683	1. 248	1. 346	. 470	1. 646	1. 862	. 637	2. 278
4/0-----	8, 696	7, 105	6, 456	. 800	. 623	1. 064	1. 136	. 443	1. 440	1. 627	. 610	2. 048
3/0-----	6, 998	5, 521	5, 119	. 653	. 563	. 912	. 964	. 417	1. 270	1. 431	. 583	1. 855
2/0-----	5, 630	4, 409	4, 061	. 522	. 503	. 775	. 808	. 390	1. 117	1. 250	. 557	1. 678
1/0-----	4, 514	3, 518	3, 219	. 424	. 465	. 679	. 695	. 373	1. 009	1. 121	. 540	1. 554
1-----	3, 614	2, 810	2, 554	. 328	. 413	. 577	. 578	. 350	. 896	. 981	. 517	1. 419
2-----	2, 893	2, 243	2, 107	. 270	. 383	. 518	. 507	. 337	. 829	. 898	. 503	1. 339

¹ Conductor loading per foot as specified in Rule 251, NESC, 5th edition.

Table 119. Bare, Copper Cable

Conductor size AWG and standing	Ultimate strength (pounds)					Loading (pounds per linear foot of conductor)								
	Overall diameter (inch)	Cross sectional area (square inch)	Hard drawn (mini- mum)	Medium hard drawn (mini- mum)	Annealed (maxi- mum)	Light loading			Medium loading			Heavy loading		
						Vertical (weight of con- ductor without ice)	Trans- verse (9-lb. wind per square foot on conductor without ice)	Con- ductor loading ¹	Vertical (con- ductor plus ¼-in. radial ice)	Trans- verse (4-lb. wind per square foot on ice- covered con- ductor)	Con- ductor loading ¹	Vertical (con- ductor plus ½-in. radial ice)	Trans- verse (4-lb. wind per square foot on ice- covered con- ductor)	Con- ductor loading ¹
4/0														
12 strand-----	0. 552	0. 1662	9, 483	7, 378	6, 149	0. 6533	0. 4140	0. 8234	0. 9027	0. 3507	1. 1584	1. 3076	. 5173	1. 6962
7 strand-----	. 522	. 1662	9, 154	7, 269	6, 149	. 6533	. 3915	. 8116	. 8934	. 3407	1. 1462	1. 2890	. 5073	1. 6752
3/0														
12 strand-----	. 492	. 1318	7, 556	5, 890	4, 876	. 5181	. 3690	. 6861	. 7489	. 3307	1. 0087	1. 1351	. 4973	1. 5293
7 strand-----	. 464	. 1318	1, 366	5, 812	4, 876	. 5181	. 3480	. 6741	. 7402	. 3213	. 9969	1. 1177	. 4880	1. 5096
2/0														
7 strand-----	. 414	. 1045	5, 926	4, 641	3, 868	. 4109	. 3105	. 5650	. 6174	. 3047	. 8785	. 9794	. 4713	1. 3769
1/0														
7 strand-----	. 368	. 08289	4, 752	3, 703	3, 066	. 3257	. 2760	. 4769	. 5179	. 2893	. 7832	. 8656	. 4560	1. 2684

1														
7 strand-----	. 328	. 06573	3, 804	2, 958	2, 432	. 2584	. 2460	. 4068	. 4382	. 2760	. 7079	. 7734	. 4427	1. 1811
3 strand-----	. 360	. 06573	3, 620	2, 875	2, 432	. 2559	. 2700	. 4220	. 4456	. 2867	. 7199	. 7908	. 4533	1. 2015
2														
7 strand-----	. 292	. 05213	3, 045	2, 361	2, 007	. 2049	. 2190	. 3499	. 3735	. 2640	. 6474	. 6975	. 4307	1. 1098
3 strand-----	. 320	. 05213	2, 913	2, 299	1, 929	. 2029	. 2400	. 3643	. 3802	. 2733	. 6582	. 7129	. 4400	1. 1278
3														
3 strand-----	. 285	. 04134	2, 359	1, 835	1, 529	. 1609	. 2138	. 3176	. 3273	. 2617	. 6091	. 6492	. 4283	1. 0678
4														
3 strand-----	. 254	. 03278	1, 879	1, 465	1, 213	. 1276	. 1905	. 2793	. 2843	. 2513	. 5694	. 5966	. 4180	1. 0185
6														
3 strand-----	. 201	. 02062	1, 205	933. 9	-----	. 08026	. 1508	. 2035	. 2205	. 2337	. 5113	. 5163	. 4003	. 9433

¹ Conductor loading per foot as specified in Rule 251, NESC, fifth edition.

Table 120. Solid Copper, Bare Wire

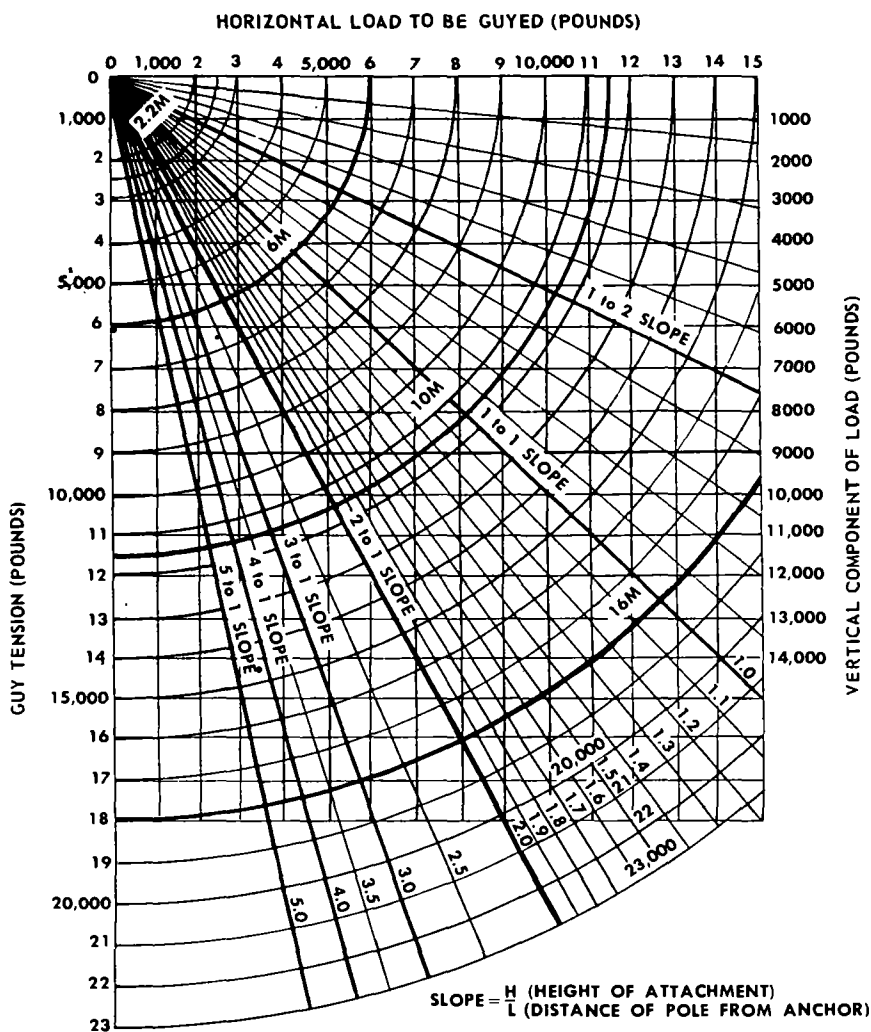
Conductor size AWG	Ultimate strength (pounds)					Loading (pounds per linear foot of conductor)								
	Overall diameter (inch)	Cross sectional area (square inch)	Hard drawn (mini- mum)	Medium hard drawn (mini- mum)	Annealed (maxi- mum)	Light loading			Medium loading			Heavy loading		
						Vertical (weight of con- ductor without ice)	Trans- verse (9-lb. wind per square foot on conductor without ice)	Con- ductor loading ¹	Vertical (con- ductor plus ¼-in. radial ice)	Trans- verse (4-lb. wind per square foot on ice- covered con- ductor)	Con- ductor loading ¹	Vertical (con- ductor plus ½-in. radial ice)	Trans- verse (4-lb. wind per square foot on ice- covered con- ductor)	Con- ductor loading ¹
4/0-----	0. 4600	0. 1662	8, 143	6, 980	5, 983	0. 6405	0. 3450	0. 7775	0. 8613	0. 3200	1. 1088	1. 2376	0. 4867	1. 6199
3/0-----	. 4096	. 1318	6, 772	5, 667	4, 745	. 5079	. 3072	. 6436	. 7130	. 3032	. 9648	1. 0737	. 4699	1. 4620
2/0-----	. 3648	. 1045	5, 519	4, 599	3, 763	. 4028	. 2736	. 5869	. 5940	. 2883	. 8503	. 9407	. 4549	1. 3349
1/0-----	. 3249	. 08289	4, 517	3, 730	2, 984	. 3195	. 2437	. 4518	. 4983	. 2750	. 7592	. 8326	. 4416	1. 2325
1-----	. 2893	. 06573	3, 688	3, 024	2, 432	. 2533	. 2170	. 3835	. 4210	. 2631	. 6865	. 7441	. 4298	1. 1493
2-----	. 2576	. 05213	3, 003	2, 450	1, 929	. 2009	. 1932	. 3287	. 3587	. 2525	. 6287	. 6720	. 4192	1. 0820
3-----	. 2294	. 04134	2, 439	1, 984	1, 530	. 1593	. 1721	. 2845	. 3083	. 2431	. 5826	. 6128	. 4098	1. 0272
4-----	. 2043	. 03278	1, 970	1, 584	1, 213	. 1264	. 1532	. 2486	. 2676	. 2348	. 5460	. 5643	. 4014	. 9825
5-----	. 1819	. 02600	1, 591	1, 265	961. 9	. 1002	. 1364	. 2193	. 2345	. 2273	. 5166	. 5242	. 3940	. 9458
6-----	. 1620	. 02062	1, 280	1, 010	762. 9	. 07946	. 1215	. 1952	. 2075	. 2207	. 4929	. 4911	. 3873	. 9155
7-----	. 1443	. 01635	1, 030	806. 6	605. 0	. 06302	. 1082	. 1752	. 1856	. 2148	. 4739	. 4636	. 3814	. 8903
8-----	. 1285	. 01297	826. 0	643. 9	479. 8	. 04997	. 09638	. 1586	. 1676	. 2095	. 4583	. 4408	. 3762	. 8695
9-----	. 1144	. 01028	661. 2	514. 2	380. 5	. 03963	. 08580	. 1445	. 1530	. 2048	. 4456	. 4218	. 3715	. 8521
10-----	. 1019	. 008155	529. 2	410. 4	314. 0	. 03143	. 07643	. 1326	. 1409	. 2006	. 4351	. 4058	. 3673	. 8373
11-----	. 09074	. 006467	422. 9	327. 6	249. 0	. 02492	. 06806	. 1225	. 1309	. 1969	. 4264	. 3924	. 3636	. 8250
12-----	. 08081	. 005129	337. 0	261. 6	197. 5	. 01977	. 06061	. 1138	. 1227	. 1936	. 4192	. 3810	. 3603	. 8144

¹ Conductor loading per foot as specified in Rule 251, NESC, fifth edition.

Table 121. Bare, Copperweld-Copper and Copperweld

Conductor size	Overall diameter (inches)	Cross sectional area (square inches)	Ultimate strength (pounds)	Loading (lb. per linear ft. of conductor)								
				Light Loading			Medium Loading			Heavy Loading		
				Vertical (conductor without ice)	Transverse (9-lb. wind per square foot on conductor ice)	Conductor loading ¹	Vertical (conductor plus ½-in. radial ice)	Transverse (4-lb. wind per square foot on ice-covered conductor)	Conductor	Vertical (conductor plus ½-in. radial ice)	Transverse (4-lb. wind per square foot on ice-covered conductor)	Conductor loading ¹
2A-----	0.366	0.06799	5,876	0.2568	0.2745	0.4258	0.4483	0.2887	0.7232	0.7953	0.4553	1.2065
3A-----	.326	.05392	4,810	.2036	.2445	.3682	.3872	.2753	.6615	.7172	.4420	1.1325
4A-----	.290	.04276	3,938	.1615	.2175	.3209	.3294	.2633	.6118	.5427	.4300	1.0716
5A-----	.258	.03391	3,193	.1281	.1935	.2821	.2860	.2527	.5716	.5994	.4193	1.0216
6A-----	.230	.02689	2,585	.1016	.1725	.2502	.2508	.2433	.5395	.5555	.4100	.9804
7A-----	.223	.02516	2,754	.09366	.1673	.2417	.2407	.2410	.5306	.5432	.4077	.9692
8A-----	.199	.01995	2,233	.07427	.1493	.2168	.2139	.2330	.5063	.5089	.3997	.9371
1/OF-----	.388	.09207	6,356	.3541	.2910	.5083	.5524	.2960	.8167	.9062	.4627	1.3075
1F-----	.346	.07303	5,266	.2809	.2595	.4324	.4462	.2820	.7349	.8069	.4487	1.2133
2F-----	.308	.05792	4,233	.2228	.2310	.3709	.3963	.2693	.6691	.7252	.4360	1.1362
4C-----	.284	.04098	3,231	.1548	.2130	.3133	.3208	.2613	.6038	.6423	.4280	1.0618
6C-----	.255	.02577	2,143	.0973	.1688	.2448	.2450	.2417	.5342	.5481	.4083	.9735
8C-----	.179	.01604	1,362	.06067	.1343	.1974	.1940	.2263	.4881	.4829	.3930	.9126
9½D-----	.174	.01539	1,743	.05646	.1305	.1922	.1883	.2247	.4832	.4755	.3913	.9059
3 No. 10-----	.220	.02446	2,882	.08713	.1650	.2366	.2332	.2400	.5246	.5348	.4067	.9619
3 No. 11-----	.196	.01940	2,286	.06910	.1470	.2124	.2078	.2320	.5015	.5019	.3983	.9310
3 No. 12-----	.174	.01539	2,040	.05480	.1305	.1915	.1866	.2247	.4821	.4739	.3913	.9046

¹ Conductor loading per foot as specified in Rule 251, NESC, 5th edition.



DIRECTIONS

1. FIND LOAD TO BE GUYED ON TOP SCALE (ACTUAL LOAD X SAFETY FACTOR)
2. PROCEED VERTICALLY TO LINE FOR SLOPE OF GUY
AREA IN WHICH THIS POINT LIES INDICATES THE PROPER SIZE OF GUY
3. FIND TENSION IN GUY WIRE BY FOLLOWING CIRCLE
4. FIND THE VERTICAL COMPONENT OF THE LOAD BY FOLLOWING A HORIZONTAL LINE TO THE SCALE ON THE LEFT

Figure 65. Load held by various guy strands at any slope.

Table 122. Maximum Loads on Single Arms Without Arm Guys

Cross arm size (inches)	Equivalent maximum allowable horizontal load at end of pin (pounds)	Equivalent maximum allowable unbalanced horizontal load at end of pin (pounds)	Equivalent maximum allowable vertical load at end of pin (pounds)
38 x 3¼ x 4¼-----	900	600	1, 000
38 x 3½ x 4¼-----	1, 000	600	1, 150
38 x 3¾ x 4¾-----	1, 300	600	1, 250
67 x 3¼ x 4¼-----	500	400	800
67 x 3½ x 4½-----	600	400	900
67 x 3¾ x 4¾-----	700	400	1, 000
96 x 3¼ x 4¼-----	400	250	600
96 x 3½ x 4½-----	500	250	750
96 x 3¾ x 4¾-----	600	250	850
120 x 3½ x 4½-----	300	200	550
120 x 3¾ x 4¾-----	400	200	650
120 x 4 x 5-----	500	200	750

Table 123. Maximum Loads on Double Arms Without Arm Guys

Cross arm size (inches)	Equivalent maximum allowable horizontal load at end of pin (pounds)	Equivalent maximum allowable unbalanced horizontal load at end of pin (pounds)	Equivalent maximum allowable vertical load at end of pin (pounds)
38 x 3¼ x 4¼-----	3, 600	1, 000	2, 000
38 x 3½ x 4½-----	4, 350	1, 000	2, 300
38 x 3¾ x 4¾-----	5, 200	1, 000	2, 500
67 x 3¼ x 4¼-----	1, 850	600	1, 600
67 x 3½ x 4½-----	2, 200	600	1, 800
67 x 3¾ x 4¾-----	2, 650	600	2, 000
96 x 3¼ x 4¼-----	1, 250	400	1, 200
96 x 3½ x 4½-----	1, 450	400	1, 500
96 x 3¾ x 4¾-----	1, 750	400	1, 700
120 x 3½ x 4½-----	1, 100	300	1, 100
120 x 3¾ x 4¾-----	1, 350	300	1, 300
120 x 4 x 5-----	1, 600	300	1, 500

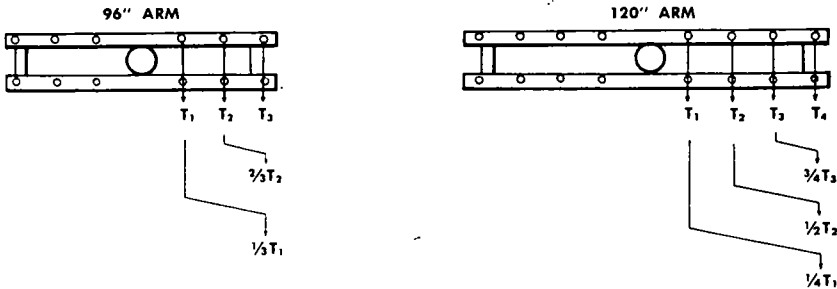


Figure 66. Equivalent load at end-pin position.

Table 124. Wire Sizes for 120-Volt Single-Phase Circuit

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG)												
			Distance one way from supply to load (feet)												
			50	75	100	125	150	175	200	250	300	350	400	450	500
15.....	14	10	14	12	10	8	8	6	6	6	4	4	4	2	2
20.....	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25.....	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30.....	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35.....	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40.....	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45.....	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50.....	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55.....	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60.....	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65.....	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	-----
70.....	8	4	6	4	2	2	1	1	0	2/0	2/0	3/0	4/0	4/0	-----
75.....	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0	-----	-----
80.....	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0	-----	-----
85.....	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0	-----	-----	-----
90.....	6	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0	-----	-----	-----
95.....	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0	-----	-----	-----	-----
100.....	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0	-----	-----	-----	-----

Table 125. Wire Sizes for 220-Volt 3-Phase Circuits

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG)												
			Distance one way from supply to load (feet)												
			100	150	200	250	300	350	400	500	600	700	800	900	1,000
15	14	12	14	12	10	8	8	8	6	6	6	4	4	4	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	6	4	4	2	2	2	2	1
30	12	8	10	8	6	6	6	4	4	2	2	2	1	1	0
35	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
40	10	6	8	6	6	4	4	4	2	1	1	1	0	0	2/0
45	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
50	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
55	8	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
60	8	6	6	6	4	2	2	2	1	0	0	2/0	3/0	3/0	4/0
65	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
70	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
75	6	4	6	4	2	2	2	1	0	2/0	2/0	3/0	4/0	4/0	-----
80	6	4	6	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0	-----
85	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0	-----	-----
90	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0	-----	-----
95	6	4	6	4	2	1	1	0	2/0	3/0	3/0	4/0	-----	-----	-----
100	4	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0	-----	-----	-----
125	4	2	4	2	1	0	2/0	2/0	3/0	4/0	-----	-----	-----	-----	-----
150	2	2	2	2	0	2/0	2/0	3/0	4/0	-----	-----	-----	-----	-----	-----
175	2	1	2	1	0	2/0	3/0	4/0	4/0	-----	-----	-----	-----	-----	-----
200	1	0	1	0	2/0	3/0	4/0	4/0	-----	-----	-----	-----	-----	-----	-----
225	0	0	0	0	2/0	3/0	4/0	-----	-----	-----	-----	-----	-----	-----	-----
250	2/0	2/0	2/0	2/0	3/0	4/0	-----	-----	-----	-----	-----	-----	-----	-----	-----
275	3/0	3/0	3/0	3/0	3/0	4/0	-----	-----	-----	-----	-----	-----	-----	-----	-----
300	3/0	3/0	3/0	3/0	4/0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
325	4/0	4/0	4/0	4/0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Table 126. Wire Sizes for 240-Volt Single-Phase Circuits

[illegible]

129. Incandescent Lamp Data

Table 127. Incandescent Lamps

Watts	Volts	Bulb type ¹	Bulb finish	Base	Rated life-hours	Purpose
10-----	120	S-14	Inside frost---	Medium	1, 500	General.
15-----	120	A-15	Inside frost---	Medium	1, 200	General.
25-----	120	A-19	Inside frost---	Medium	1, 000	General.
25-----	120	A-19	Ruby-----	Medium	1, 000	Photography.
25-----	120	T-10	Clear-----	Medium	1, 000	Showcase.
25-----	220	A-19	Inside frost---	Medium	1, 000	General.
40-----	120	A-19	Inside frost---	Medium	1, 000	General.
50-----	120	A-19	Rough service	Medium	1, 000	Automotive, mechanics, etc.
50-----	230	A-19	Inside frost---	Medium	1, 000	General.
60-----	120	A-19	Inside frost---	Medium	1, 000	General.
100-----	120	A-21	Inside frost---	Medium	750	General.
100-----	220	A-23	Inside frost---	Medium	750	General.
150-----	120	PS-25	Inside frost---	Medium	750	General.
200-----	120	PS-30	Inside frost---	Medium	750	General.
200-----	230	PS-30	Inside frost---	Medium	750	General.
300-----	120	PS-35	Inside frost---	Medium	750	General.
300-----	120	PS-35	Inside frost---	Mogul--	1, 000	General.
500-----	120	PS-40	Inside frost---	Mogul--	1, 000	General.
500-----	230	PS-40	Inside frost---	Mogul--	1, 000	General.
750-----	120	PS-52	Inside frost---	Mogul--	1, 000	General.
1,000-----	120	PS-52	Inside frost---	Mogul--	1, 000	General.
1,500-----	120	PS-52	Inside frost---	Mogul--	1, 000	General.

¹ Stocked in theaters of operations.

130. Lighting in Theater-of-Operations Construction

Where facilities permit, the following wattages are suggested for lighting in theater-of-operations buildings.

	Watts per square foot of floor area
Barracks, quarters-----	0. 10
Storage, wards, heater, toilets, warehouses-----	. 20
Messhalls, waiting, and living spaces-----	. 30
Recreation, bathhouses, kitchens, general work spaces, noncritical-----	. 50
Reading, laboratories, barber, tailor, post exchange, pharmacy, work spaces-----	. 75
Offices, laundry, shops—low mounting heights up to 10 feet (repair or production)-----	1. 00

131. Miscellaneous Electrical Data

a. Number of Insulated Wires Allowed in Various Sized Conduits.
See table 128.

b. Number of conductors in a box.

(1) Table 129 gives the maximum number of conductors, not counting fixture wires, permitted in outlet and junction

boxes. This table applies where no fittings or devices, such as fixture studs, cable clamps, hickey, switches, or receptacles are contained in the box. Where one or more fixture studs, cable clamps, or hickey are contained in the box, the number of conductors shall be one less than shown in the tables, with a further deduction of one conductor for one or several flush devices mounted on the same strap. A conductor running through the box is counted as one conductor and each conductor originating outside the box and terminating inside the box is counted as one conductor. Conductors of which no part leaves the box are not to be counted in the above computation. If single flush boxes are ganged, and each section is occupied by a flush device or combination of flush devices on the same strap, the limitations will apply to each section individually.

(2) Table 130 applies for combinations not shown in table 129.

c. *Full-load Current and Circuit-breaker Sizes for Alternating-current Motors.* See table 130.

Table 128. *Number of Insulated Wires Allowed in Various Sized Conduits*

Size AWG MCM	1	Number of conductors in one conduit or tubing							
		2	3	4	5	6	7	8	9
18-----	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$
16-----	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
14-----	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1
12-----	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	$1\frac{1}{4}$
10-----	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$
8-----	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$
6-----	$\frac{1}{2}$	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	2	2
4-----	$\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	2	2	$2\frac{1}{2}$
3-----	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	2	2	$2\frac{1}{2}$	$2\frac{1}{2}$
2-----	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	2	2	2	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$
1-----	$\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	3	3
0-----	1	$1\frac{1}{2}$	2	2	$2\frac{1}{2}$	$2\frac{1}{2}$	3	3	3
00-----	1	2	2	$2\frac{1}{2}$	$2\frac{1}{2}$	3	3	3	$3\frac{1}{2}$
000-----	1	2	2	$2\frac{1}{2}$	3	3	3	$3\frac{1}{2}$	$3\frac{1}{2}$
0000-----	$1\frac{1}{4}$	2	$2\frac{1}{2}$	3	3	3	$3\frac{1}{2}$	$3\frac{1}{2}$	4
250-----	$1\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	3	3	$3\frac{1}{2}$	4	4	5
300-----	$1\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	4	5	5
350-----	$1\frac{1}{4}$	3	3	$3\frac{1}{2}$	$3\frac{1}{2}$	4	5	5	5
400-----	$1\frac{1}{2}$	3	3	$3\frac{1}{2}$	4	4	5	5	5
500-----	$1\frac{1}{2}$	3	3	$3\frac{1}{2}$	4	5	5	5	6

Table 129. Number of Conductors Allowed in Boxes of Certain Sizes

Deep boxes				
Box dimensions—Trade size	Maximum number of conductors			
	No. 14	No. 12	No. 10	No. 8
1½ x 3¼ octagonal.....	5	5	4	0
1½ x 4 octagonal.....	8	7	6	5
1¼ x 4 square.....	9	7	6	4
1½ x 4 square.....	11	9	7	5
1½ x 4 ¹ / ₁₆ square.....	16	12	10	8
2½ x 4 ¹ / ₁₆ square.....	20	16	12	10
2 x 1¾ x 2¾.....	5	4	4	-----
2½ x 1¾ x 2¾.....	6	6	5	-----
3 x 1¾ x 2¾.....	7	7	6	-----

Where there is not sufficient space for a deeper box, four No. 14 AWG conductors may enter a box provided with cable clamps and contain one or more devices on a single mounting strap.

Shallow Boxes of Less Than 1½" Depth

Box dimensions—Trade size	Maximum number of conductors		
	No. 14	No. 12	No. 10
3¼.....	4	4	3
4.....	6	6	4
4 ¹ / ₁₆	8	6	6

Table 130. Number of Conductors Allowed in Boxes, Other Combinations

Size of conductor	Frec space within box for each conductor
No. 14.....	2 cubic inches.
No. 12.....	2.25 cubic inches.
No. 10.....	2.5 cubic inches.
No. 8.....	3 cubic inches.

Table 131. Full-Load Current and Circuit-Breaker Sizes for Alternating-Current Motors

Motor horsepower	Single phase				Three phase			
	110 volt		220 volt		220 volt		440 volt	
	Current (amps)	Circuit-breaker size (amps)	Current (amps)	Circuit-breaker size (amps)	Current (amps)	Circuit-breaker size (amps)	Current (amps)	Circuit-breaker size (amps)
1/8-----	3. 34	15	1. 67	15	-----	-----	-----	-----
1/4-----	4. 8	15	2. 4	15	-----	-----	-----	-----
1/2-----	7	15	3. 5	15	2. 5	15	1. 3	15
3/4-----	9. 4	25	4. 7	15	2. 8	15	1. 4	15
1-----	11	25	5. 5	15	3. 3	15	1. 7	15
1 1/2-----	15. 2	35	7. 6	25	4. 7	15	2. 4	15
2-----	20	50	10	25	6	15	3	15
3-----	28	50	14	35	9	25	4. 5	15
5-----	46	70	23	50	15	35	7. 5	15
7 1/2-----	68	125	34	70	22	50	11	25
10-----	86	200	43	70	27	50	14	35
15-----	-----	-----	-----	-----	38	70	19	50
20-----	-----	-----	-----	-----	52	125	26	70
25-----	-----	-----	-----	-----	64	125	32	70
30-----	-----	-----	-----	-----	77	125	39	70
40-----	-----	-----	-----	-----	101	200	51	125
50-----	-----	-----	-----	-----	125	200	63	125
60-----	-----	-----	-----	-----	149	225	75	125
75-----	-----	-----	-----	-----	180	400	90	200
100-----	-----	-----	-----	-----	246	400	123	200

Section V. SPECIAL UTILITIES

132. Refrigerated Warehouses

a. General. Table 132 gives basic data on T/O refrigerated warehouses. For further details see TM 5-302.

b. Types and Capacities. For preliminary planning in areas where refrigerated storage is needed primarily for frozen meat, a storage capacity of 0.02 cubic feet per man per day is satisfactory. For storing all components of the field ration, at least three compartments are needed; one for frozen meat because of the low temperature required, one for butter and shelled eggs because they are contaminated easily by other foods, and one for smoked meats, fruits, and vegetables. The controls are normally operated to maintain temperatures of 10° F. for frozen meat and 34° F. for other foods.

c. Illustrative Situations.

- (1) *Problem.* To select refrigerated warehouse capacity suitable for 30-day storage of rations for 20,000 men.

(2) *Solution.* This is equivalent to 60-day storage for 10,000 men. Table 132 shows that the following are adequate—

	<i>Rations (men for 60 days)</i>
For frozen beef, 2 warehouses 20' x 100'-----	11, 880
For butter and shelled eggs, 1 warehouse 20' x 100'-----	10, 560
All other items:	
4 warehouses 20' x 100'-----	9, 520
1 warehouse 20' x 55'-----	1, 080

Table 132. *Sizes and Capacities of T/O Refrigerated Warehouses, Standard Frame*

Nominal size	20' x 55'	20' x 100'	80' x 220'
Inside dimensions (feet)-----	18' x 40'-----	18' x 88'-----	77.5' x 197'
Gross floor area (square feet)-----	720-----	1,584-----	15,267
Ceiling height (feet)-----	8-----	8-----	14.5
Height of stack (feet)-----	6-----	6-----	12
Equipment-----	2 compressors (20,000 B.t.u. per hour). 1 evap con- denser. 1 cooling tower. 2 unit coolers.	2 compressors (40,000 B.t.u. per hour). 1 evap con- denser. 1 cooling tower. 4 unit coolers.	1 compressor (78,000 B.t.u. per hour). 2 compressors (180,000 B.t.u. per hour). 1 evap con- denser. 1 receiver. 20 unit coolers.

Storage capacity

Frozen packaged boned beef:			
Total pounds-----	81,000-----	178,200-----	
Total rations-----	162,000-----	356,400-----	
Men for 60 days-----	2,700-----	5,940-----	
Butter and shelled eggs:			
Total pounds, butter-----	36,000-----	79,200-----	
Total pounds, eggs-----	36,000-----	79,200-----	
Total combined rations-----	288,000-----	633,600-----	
Men for 60 days-----	4,800-----	10,560-----	
Ham, bacon, bologna, pota- toes, onions, and citrus fruits. ¹			
Total pounds, ham, bacon and bologna.	10,200-----	22,440-----	
Total pounds, other items-----	45,500-----	100,030-----	
Total combined rations-----	65,000-----	142,900-----	
Men for 60 days-----	1,080-----	2,380-----	

¹ Equal rations of each item.

133. Refrigerant Properties

Table 133. Refrigerant Properties

	Ammonia (NH ₃)	Freon (F-12) (CCl ₂ F ₂)	Freon (F-22) CHClF ₂	Methyl chloride (CH ₃ Cl)
Critical temperature	271° F	233° F	204.8° F	290° F.
Flammability	Burns if heated. May explode under certain conditions.	Nonflammable and nonexplosive.	Nonflammable and nonexplosive.	Flammable but does not burn readily. Explosive under certain conditions.
Effect on metals	Reacts with copper and brass if water vapor is present. Slight effect on iron and steel.	Noncorrosive	Noncorrosive	Noncorrosive.
Effect on lubricants	No effect if ammonia is anhydrous. If moisture is present, tends to form emulsion.	No effect. Mixes with oil in all proportions.	No effect. Mixes with oil in all proportions.	Dissolves all kinds of oil. Glycerine and white mineral oils must be used.
Effect on personnel	Injurious if exposure is prolonged and gas concentration is above 1/10 of 1 percent. Very irritating to eyes and nose.	Practically non-toxic.	Practically non-toxic.	Concentration of 2 percent to 2 1/2 percent for 2 hours may cause death.
Tests for leaks	By smell. Exact location found with sulfur candles. ¹	(²)	(²)	Smells like chloroform. Alcohol flame in methyl chloride has greenish tinge.

¹ Forms white fog when burned in presence of ammonia.

² Halide lamp usually used. This consists of a flame-heated copper wire which in contact with freon burns with a blue-green color.

134. Iceplant Characteristics

Table 134. Iceplants

	1-ton	3.6-ton	15-ton
Stock No.....	66-5710.01-0	66-5710.06-0	66-5710.15-0
Weight (pounds crated for export).....	10, 200	27, 500	120, 600
Cubage (cubic feet crated for export).....	427	1, 314	4, 950
Connected electrical load.....	None	12.24 kv.-a. 11.40 kv.-a.	57. 76 55. 26

135. Air Conditioning

a. *Authorized Uses.* In tropical climates air conditioning is used in hospitals or installations to protect patients or mechanical equipment from excess heat and humidity. Its use is not authorized to provide comfort for personnel in normal health even though it might increase efficiency. Air conditioning is used in all climates for certain photographic reproduction processes and for the repair and adjustment of instruments; for example, some types of radar and bombsight equipment require controlled temperature and humidity.

b. *Standard Unit.* The standard Army air-conditioning unit developed for use in theater-of-operations construction is self-contained, water-cooled, and powered by a 5-horsepower motor. It has a capacity of 70,000 British thermal units per hour. In tropical temperatures, one unit will air-condition a space 20 by 20 feet (or equivalent) with 100 percent fresh-cooled air, or a space 20 by 40 feet (or equivalent) with 33 percent fresh air and 67 percent reconditioned air. The unit consists of an air-handling cabinet 8 feet high 4 feet wide, and 1 foot 8 inches deep and a cooling tower 8 feet high, 4 feet wide, and 2 feet 6 inches deep. The shipping weight and cubage of both items are 3,745 pounds and 206 cubic feet.

136. Boilers and Accessories

a. *Types and Rating.*

Type	Rating (boiler horse- power)
Vertical steel fire tube.....	15 25 35 60
Horizontal steel fire tube.....	200
Portable steel firebox.....	143

b. Other data.

Table 135. Data on Boiler Feed Pumps

Size	3 x 2 x 3	4½ x 3 x 4	5¼ x 3½ x 5
Minimum capacity of pump, (gallons per minute)-----	6	10	25
Maximum piston speed (feet per minute)---	14	20	25
Size of steam inlet (inches)-----	¾	¾	¾
Size of exhaust outlet (inches)-----	¾	2	2
Size of water suction (inches)-----	2	2	2
Size of water discharge (inches)-----	¾	¾	2
Weight, crated for export (pounds)-----	350	400	600
Cubage, crated for export (cubic feet)-----	5	7	10

Table 136. Data on Feed-Water Heaters

Coil surface (sq. ft.) minimum	20	30	75
Condensing capacity (pounds per hour)-----	100	160	400
Water flow (gallons per minute) minimum--	6	10	25
Steam-supply connection (inches)-----	¾	2	2
Condensate connection (inches)-----	¾	¾	¾
Water inlet and outlet (inches)-----	¾	¾	22
Safety valve (inches)-----	¾	¾	1½
Connections to oil separator (inches)-----	¾	¾	2
Grease trap, inlet and outlet (inches)-----	¾	¾	¾
Float and thermostatic trap inlet and outlet (inches)-----	¾	¾	¾
Weight, crated for export (pounds)-----	225	250	325
Cubage, crated for export (cubic feet)-----	9	11	13

Table 137. Data on Surge Tanks

Capacity (gal)	72	145	185
Tank dimensions-----	24 by 42	24 by 72	30 by 60
Installed position-----	Horizontal	Horizontal	Vertical
Condensate return connection (inches)--	2	2	2
Feed-water connection (inches)-----	¾	¾	¾
Vent connection (inches)-----	2	2	2
Pump suction connection (inches)-----	2	2	2
Drain connection (inches)-----	¾	¾	¾
Weight, crated for export (pounds)-----	560	800	900
Cubage, crated for export (cubic feet)----	18	25	30

Table 138. Data on Storage Type Hot-Water Generators

Storage capacity (gal)	750	365	220
Diameter of shell (inches)-----	48	36	30
Length of shell (inches)-----	96	84	72
Shell thickness (inches) minimum----	0. 312	0. 250	0. 187
Coil heating surface (square feet) minimum-----	33	10	5
Tappings for hot- and cold-water con- nections (inches)-----	1 4	2	2
Tappings for steam, condensate, re- lief, and drain connections (inches)---	2	2	2
Combination temperature and pres- sure-relief valve (capacity in Brit- ish thermal units)-----	1, 000, 000	300, 000	300, 000
Size of temperature regulating valve (inches)-----	1½	1	¾
Weight, crated for export (pounds)---	2, 250	1, 700	1, 200
Cubage, crated for export (cubic feet)-	112	86	60

¹ Four-inch connections are flanged with threaded cast-iron companion flanges and necessary nuts, bolts, and gaskets.

Table 139. Data on Boilers

Stock No.	Item
4410-277-3139	Boiler, steam, high pressure, horizontal; horsepower not rated, 400 lb. steam; forced or induced draft, oil fired.
4410-277-5871	Boiler, steam, high pressure, horizontal; 200 hp., 6,900 lb. steam; forced draft; oil fired, w/27 accessories.
4410-277-3147	Boiler, steam, high pressure, vertical; 60 hp., steam delivery not rated; induced draft, coal fired, hand, or oil fired.

137. Steam Generators

Table 140. Steam Generators

Rating pounds of steam per hour	400	200
Weight, crated for export (pounds)-----	4, 000	3, 000
Cubage, crated for export (cubic feet)-----	160	120
Condensate pump (gallons per minute)-----	3	1½
Condensate receiver, capacity (gallons)-----	10	10
Oil burner (gallons per hour at rated capacity)-----	4	2
Connections (inches):		
Condensate return-----	¾	¾
Make-up water-----	¾	¾
Blowoff (blowdown)-----	¾	¾
Steam supply-----	2	2
Motor, fan (horsepower)-----	¾	¾
Motor, condensate pump (horsepower)-----	¾	¾

138. Utilities Requirements of Mess Buildings

Table 141. Mess Building Utilities

	Troop	Hospital							
		Patients (1,000- and 750-bed)	Patients (500- and 250-bed)	(100 5-bed)	Detachment (1,000- and 750-bed)	Detachment (500-bed)	Officers and nurses (1,000- and 750-bed)	Officers and nurses	
								(250-bed)	(500-bed)
Size:									
Seating capacity-----	120	256	224	112	224	176	168	56	96
Feeding capacity-----	170	300	300	280	300	280	280	112	170
Kitchen feeding (maxi- mum) capacity-----	⁹ 170	1, 000	500	280	500	280	280	170	170
TO number, TM 5-280---	11. 10A	35. 17 sheet 1	35. 17 sheet 2	35. 17 sheet 3	35. 17 sheet 4	35. 17 sheet 5	35. 17 sheet 6	35. 17 sheet 7	
Climate-----	Temp	Temp	Temp	Temp	Temp	Temp	Temp	Temp	
Equipment:									
Range, cooking-----	2	10	5	3	5	3	3	2	
Bain marie, 72" by 36"-----		1					1		
Water heater, 50-gal. per hour (58° F. rise)-----	1								
Range boiler, 82-gal-----	1								
Hot-water generator, 10 sq. ft., 330-gal-----		1		1	1	1	1		
Hot-water generator, 5 sq. ft., 220-gal-----								1	
Refrigerator, US No. 20-----				1				1	
Refrigerator, US No. 45 ² -----		1	1		1	1	1		
Dishwasher, 180-DA-----		1	1						
Dishwasher, 50-SM-----				³ 1			³ 1	³ 1	

Steam generator ⁴ (self-contained) 200-lb. per hour								1	
Steam generator ⁴ (self-contained) 400-lb. per hour		1	1	1	1	1	1		
Power:									
Basic plan ¹ (with dishwasher)	(⁵)				(⁵)				
Light		2. 49	2. 09	0. 81		1. 38	1. 22	0. 71	0. 81
Power		2. 80	2. 80	2. 50		0. 30	2. 80	2. 80	2. 80
Total kilovolt-amperes		5. 29	4. 89	3. 31		1. 68	4. 02	3. 51	3. 61
Alternate plan ¹ (without dishwasher)						(⁶)			
Light	0. 90	2. 49	2. 09	0. 81	1. 58		1. 22	0. 71	0. 81
Power			0. 60	0. 30	0. 30				
Total kilovolt-amperes	0. 90	2. 49	2. 69	1. 11	1. 88		1. 22	0. 71	0. 81
Water consumption ⁷ (estimated):									
Gallons per day (maximum) with hand washer (alternate plan)	3, 100	18, 000	9, 000	5, 000	9, 000		5, 000	3, 100	3, 100
Gallons per day (maximum) with machine washing (basic plan)		15, 000	7, 500	4, 200		4, 200	4, 200	2, 600	2, 600

¹ See TM 5-302 for layout and drawings.² Replaced with US 65 refrigerator.³ Same as type A, 2,000-plate dishwasher.⁴ See par. 137.⁵ No basic plan.⁶ No alternate plan.⁷ Based on 6 gal. per person per day with hand dishwashing and 5 gal. per person per day with machine dishwashing.⁸ For patients, detachment, officers, and nurses.⁹ Capacity based on use of heavy-duty ranges.

CHAPTER 9

STRUCTURAL DESIGN DATA

Section I. DESIGN LOADS

139. General

This chapter provides data for the design or classification of non-standard fixed bridges, buildings, and similar structures required for temporary use in theaters of operation, based on the use of standard or commercial construction materials. The data for wind loads and impact loads on bridges has been simplified so as to eliminate many factors normally considered in bridge design. For bridge structures of a more permanent type, refer to the latest editions of The American Association of State Highway Officials, Standard Specifications for Highway Bridges, and American Railway Engineering Association Specifications. For designs based on materials differing from those in general use in the United States, modifications in values of working stresses may be required. Safe loads for standard and prefabricated bridges and buildings are given elsewhere in this text or in appropriate technical manuals. In general, information on structural design of the various materials is simplified and elementary, and does not point out all the details to be considered in making designs. It is intended to be used under the guidance of persons with enough experience in design to recognize this.

140. Dead Loads

a. General. The weights of the elements of a structure are computed and combined as required for the design of each structural member. Utilities, such as water tanks, which are an integral part of a structure are included in dead loads. Structural members are designed using assumed values for their own weights, then redesigned if necessary.

b. Highway Bridge Floor and Stringers. Tables 142, 143, and 144 give dead load in pounds per linear foot of bridge, for three types of bridge.

c. Wood-Roof Trusses. Preliminary allowances for the weight of wood-roof trusses, in pounds per square foot of horizontal projection of the area supported, are:

- (1) Pitched trusses, $0.064 L$.
- (2) Flat-top Pratt trusses, $0.043 L \div 1.75$.
- (3) Bowstring trusses, $0.038 L \div 0.60$.

Where L =span of truss in feet.

Table 142. Dead Load in Pounds Per Foot of Bridge—6-Inch Timber Floor with Timber Stringers, Curb, and Railing

Class	Type	Span in feet												
		13	14	15	16	17	18	19	20	21	22	23	24	25
8-----	Single-lane 14'-roadway	400	410	410	420	420	430	430	440	440	450	450	460	460
	Double-lane 24'-roadway	640	650	660	670	680	690	690	700	710	720	730	740	740
24-----	Single-lane 14'-roadway	460	470	480	490	500	510	510	520	530	540	550	560	560
	Double-lane 24'-roadway	730	750	770	790	810	820	840	860	880	900	920	930	950
70-----	Single-lane 14'-roadway	500	530	560	580	610	640	660	690	720	740	770	800	820
	Double-lane 24'-roadway	840	880	930	970	1, 020	1, 050	1, 090	1, 130	1, 170	1, 220	1, 260	1, 300	1, 340

Table 143. Dead Load in Pounds Per Foot of Bridge—Steel Stringers with 6-Inch Timber Floor—Timber Curb, and Railing

Class	Type	Span in feet								
		20	30	40	50	60	70	80	90	100
8-----	Single-lane 14'-roadway	480	520	560	600	630	670	710	750	780
	Double-lane 24'-roadway	770	840	900	970	1, 030	1, 100	1, 160	1, 220	1, 280
24-----	Single-lane 14'-roadway	570	620	660	710	750	800	840	890	930
	Double-lane 24'-roadway	940	1, 010	1, 080	1, 150	1, 220	1, 290	1, 360	1, 430	1, 500
70-----	Single-lane 14'-roadway	650	740	830	920	1, 010	1, 100	1, 190	1, 280	1, 370
	Double-lane 24'-roadway	1, 050	1, 210	1, 370	1, 530	1, 690	1, 850	2, 010	2, 170	2, 320

Table 144. Dead Load in Pounds Per Foot of Bridge—Steel Stringers with 6-Inch Concrete Floor and Concrete Curb—Timber Railing

Class	Type	Span in feet								
		20	30	40	50	60	70	80	90	100
8-----	Single-lane 14'-roadway-----	1, 500	1, 560	1, 610	1, 670	1, 720	1, 780	1, 830	1, 880	1, 930
	Double-lane 24'-roadway-----	2, 250	2, 330	2, 400	2, 480	2, 550	2, 630	2, 700	2, 780	2, 850
24-----	Single-lane 14'-roadway-----	1, 580	1, 650	1, 720	1, 790	1, 860	1, 930	2, 000	2, 070	2, 140
	Double-lane 24'-roadway-----	2, 360	2, 480	2, 590	2, 700	2, 810	2, 920	3, 030	3, 140	3, 250
70-----	Single-lane 14'-roadway-----	1, 660	1, 770	1, 880	1, 980	2, 100	2, 210	2, 320	2, 430	2, 540
	Double-lane 24'-roadway-----	2, 480	2, 680	2, 880	3, 080	3, 270	3, 470	3, 670	3, 870	4, 060

d. *Steel-Roof Trusses.*

$$w = \frac{pL}{150 + 5L + \frac{pS}{3}}$$

Where w = weight of truss in pounds per square foot of horizontal projection of the area supported.

p = total load in pounds per square foot of horizontal projection of the area supported.

L = span of truss in feet.

S = spacing of trusses in feet.

e. *Weights of Materials.* The weights of materials, given for estimating live loads in paragraph 141 and others given in chapter 10, are also useful in estimating dead loads of structures.

141. Live Loads

a. *Highway Bridges.* Each highway bridge is posted to indicate the class of vehicles that can make a normal crossing under the following conditions: Vehicle traveling in designated lane; maximum speed for critical vehicles 25 miles per hour; no sudden stopping or acceleration; vehicles spaced at least 30 yards tail to head. The loading applies to each lane for bridges more than one lane wide. Maximum shears and reactions normally occur when one vehicle per lane has its rear axle just over the gap side of an abutment or pier; maximum moment occurs when one vehicle per lane is near the center of the span. To determine the moment and shear caused by the design class vehicle, use the charts in figure 67 (1) through (7). These values are for one-lane, and should be doubled for two-lane bridges. Also, due to the non-uniform lateral distribution of loads through the axles or tracks of military vehicles, a lateral distribution factor of 1.5 is applied to live and impact loads in designing bridge members for moment, shear, and bearing. Allowable deflection for military highway bridge is $\frac{1}{215}$ of the span.

b. *Railroad Bridges.* Cooper's E-45 loading (fig. 68) is used in design. The moments, shears, and pier reactions produced by this loading, for each rail, are tabulated in paragraph 148. The table also gives equivalent uniform loads, per rail, for each span length.

c. *Floor Loads for Buildings.*

(1) *Uniformly distributed loads.*

(2) *Weights of materials.* Assuming normal aisles and working spaces, the weights of various materials which are used in estimating warehouse live loads are shown in table 146.

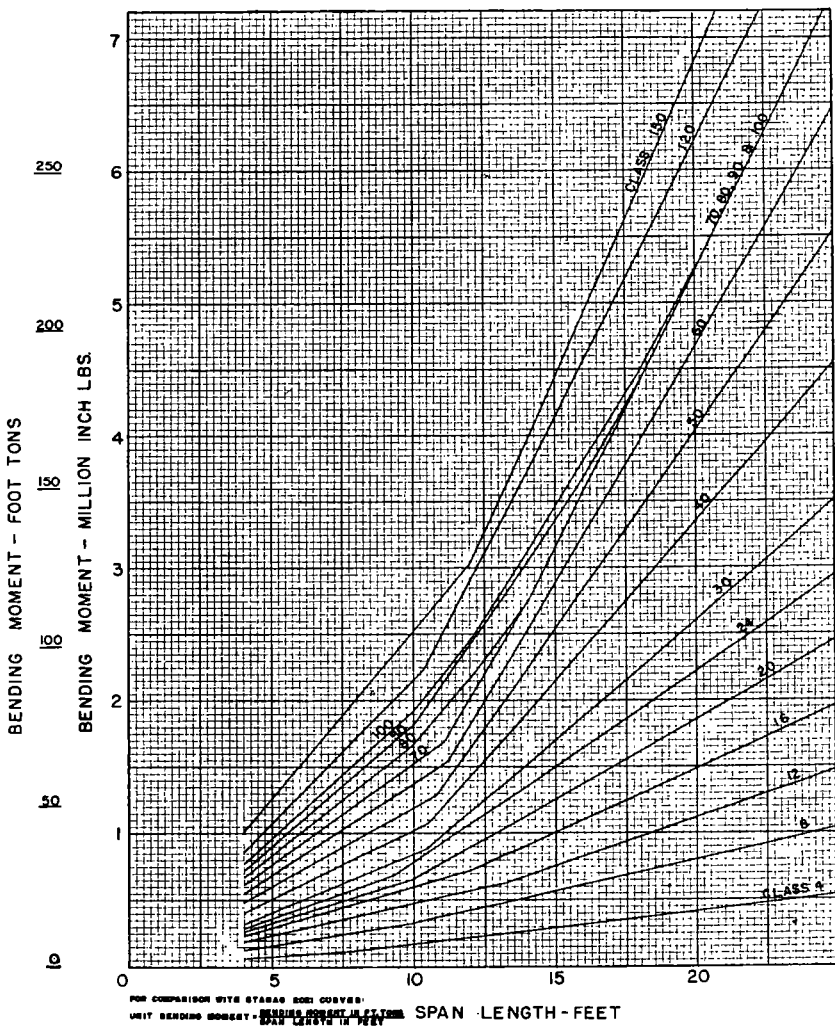
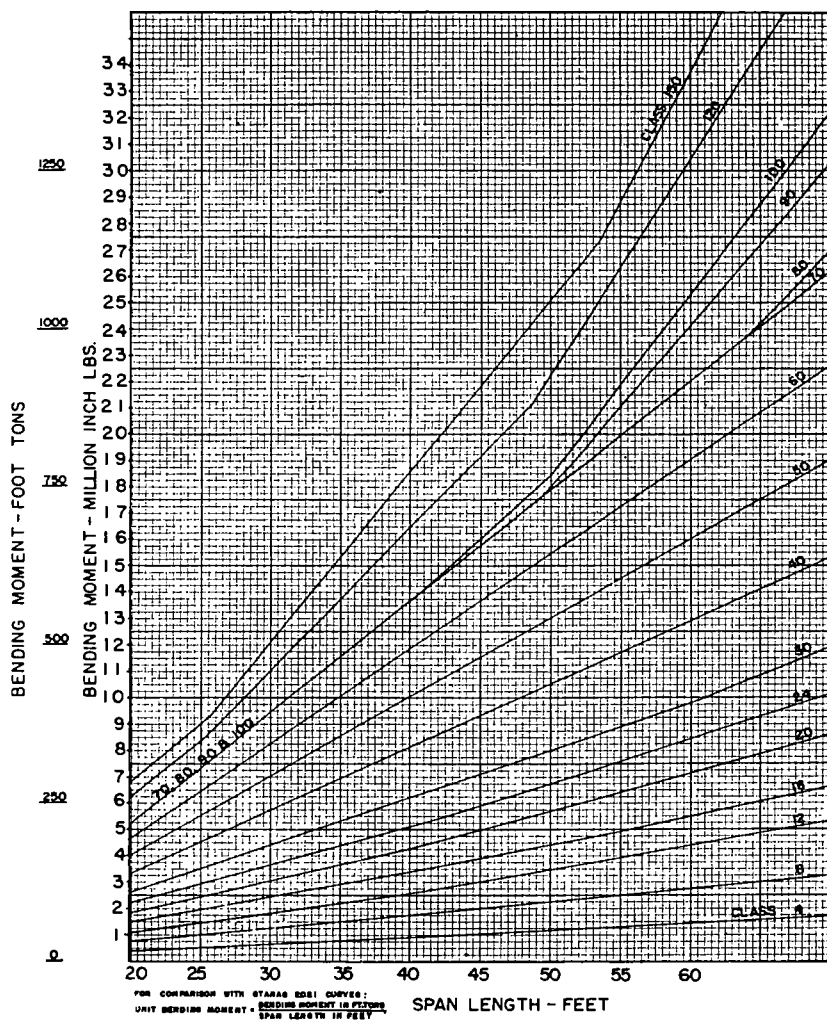


Figure 67(1). Standard class curves (moment) 0'-20' spans.



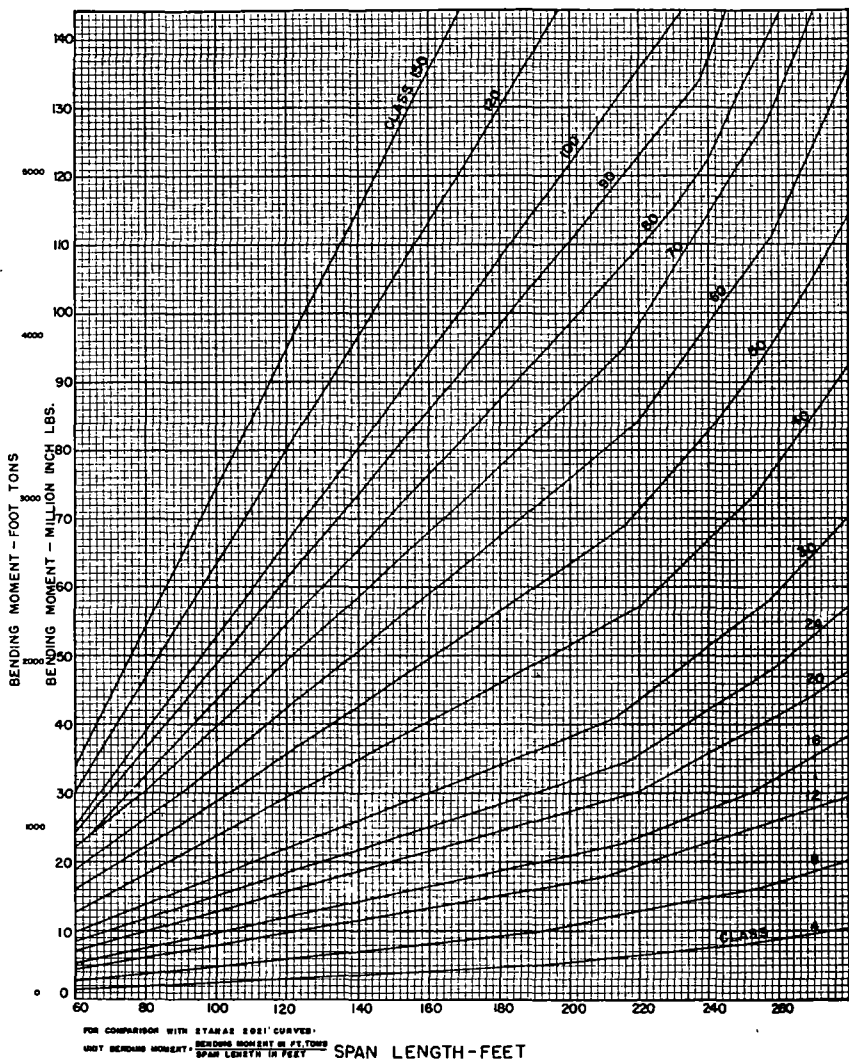


Figure 67(3). Standard class curves (moment) 60'-260' spans.

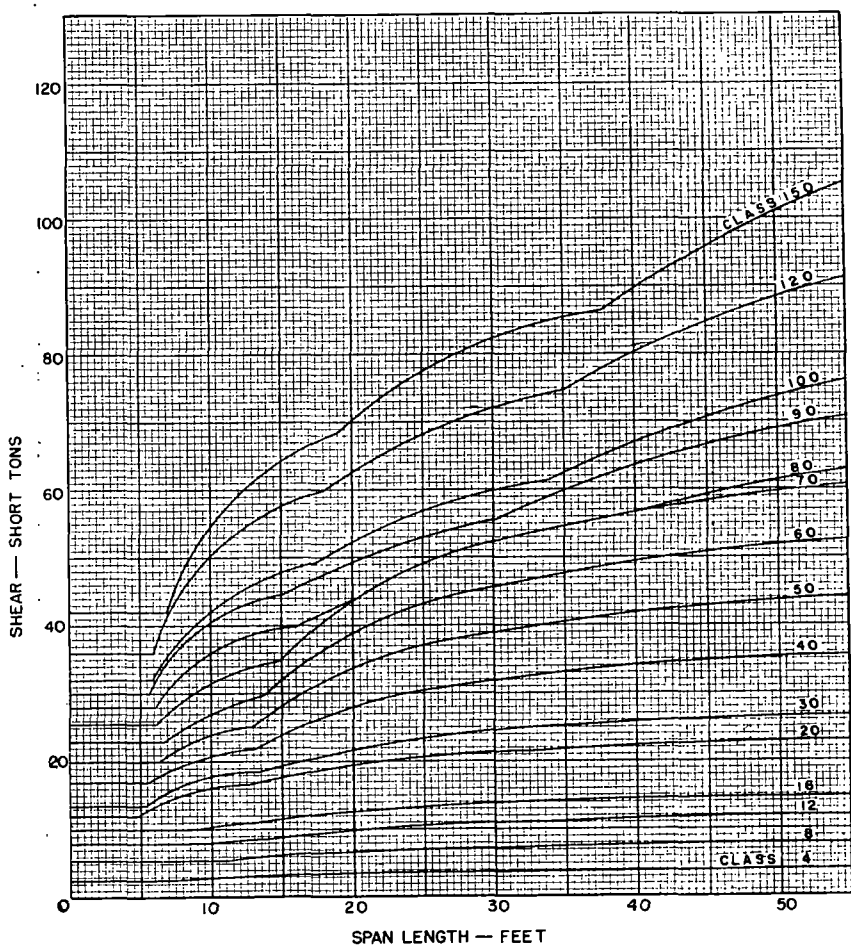


Figure 67(4). Standard class curves (shear) 0'-55' spans.

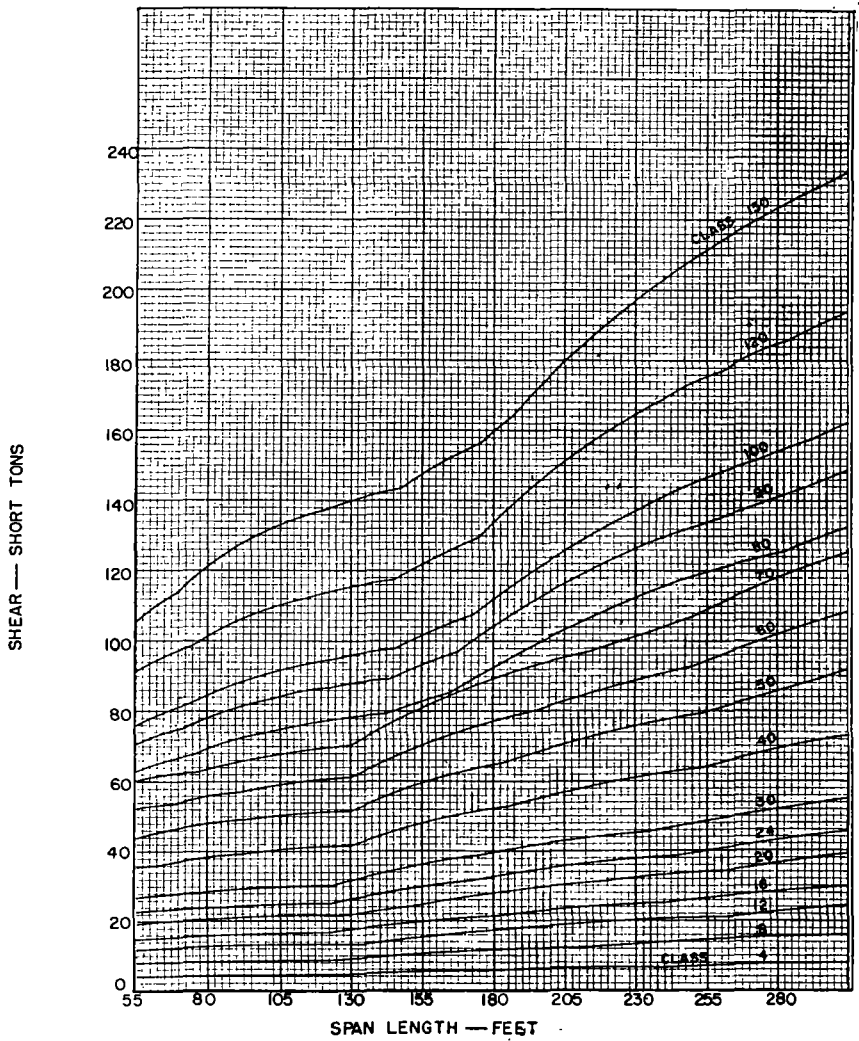
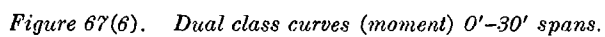
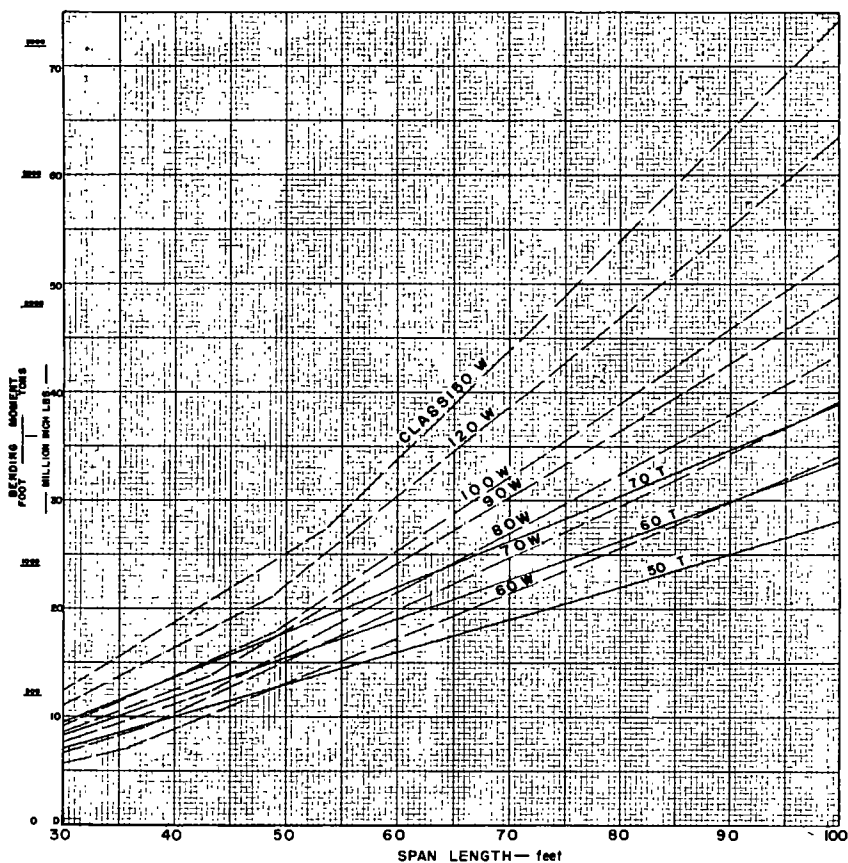


Figure 67(5). Standard class curves (shear) 55'-280' spans.





STEPS: 1. DETERMINE THE MAXIMUM MOMENT CARRYING CAPACITY (RESISTING MOMENT) OF THE BRIDGE TO BE CLASSIFIED.
 2. DRAW A HORIZONTAL LINE THROUGH THE VALUE REPRESENTING THIS MOMENT AND A VERTICAL LINE THROUGH THE SPAN LENGTH USED AND NOTE THE POINT OF INTERSECTION.
 3. THE DUAL CLASSIFICATION NUMBER OF THE BRIDGE IS THEN DETERMINED BY USING THE DASHED LINES FOR WHEELED VEHICLES AND THE SOLID LINES FOR TRACKED VEHICLES.

Figure 67(?). Dual class curves (moment) 30'–100' spans.

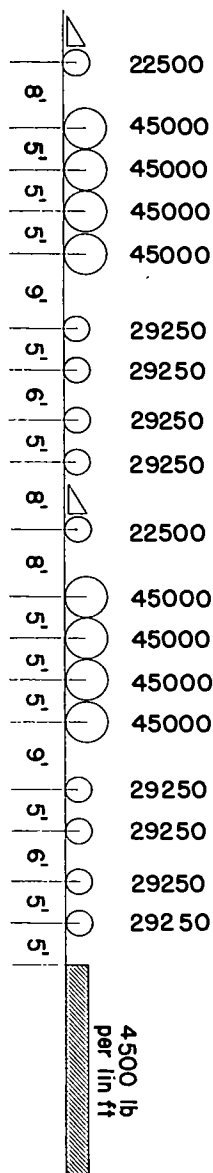


Figure 68. Bridge live load equivalents.

Table 145. Uniformly Distributed Loads

Use or occupancy	Live load in pounds ¹ per square foot
Barracks and small mess and assembly buildings.....	40
Offices.....	50
Hospital operating rooms.....	60
Mess and assembly rooms with fixed seats.....	60
Other assembly rooms and gymnasiums.....	100
Garages, passenger cars only.....	75
Garages, trucks, less than 3 tons including load.....	100
Garages, trucks, 3 to 10 tons including load.....	150
Garages, trucks, over 10 tons including load.....	200
Warehouses, light storage.....	125
Warehouses, heavy storage.....	² 250

¹ If special conditions of use are indicated, the necessity for using heavier values will be investigated.

² Minimum for any type of materials-handling equipment. Increase as required for heavy-duty materials-handling equipment and for high stocking of materials.

(3) *Concentrated loads.* For office floors, provision is made for a load of 2,000 pounds placed on any space 2½ feet square wherever this load upon an otherwise unloaded floor produces stresses greater than those caused by a uniformly distributed load of 50 pounds per square foot. In designing floors in buildings for other purposes, the actual live load caused by the use to which the building is to be put is used in the design of the building or part thereof, and special provision is made for machine or apparatus loads when these result in a greater load than is given in (1) above.

(4) *Partition loads.* In buildings designed for live loads less than 100 pounds per square foot, an assumed partition load of 300 pounds per linear foot of masonry partition, or the actual computed partition load, if greater, is used in the design. For permanent or semipermanent buildings not initially divided by partitions, allowance is made in live loads on this basis for future partitions.

d. Live-Load Reductions.

(1) No live-load reductions are made in roof members nor in buildings used for assembly purposes. In other buildings designed for live loads of 100 pounds or less per square foot, the design live load on any member carrying 150 square feet or more may be reduced at the rate of 0.08 percent per square foot of area supported by the member. The reduction shall

not exceed 60 percent nor shall it exceed $100 \times \frac{D+L}{4.33 L}$ where

D is dead load and L is live load, both in pounds per square foot of area supported by the member.

Table 146. Material Weights

Material ¹	Weight of material per cu ft of space (pounds)	Height of pile (feet)	Weight per sq ft of floor (pounds)	Recommended live load (pounds per square foot)
Building materials:				
Bricks.....	45	6	270	300
Portland cement.....	72 to 105	6	432 to 630	to
Lumber.....	45	6	270	400
Painting materials:				
Linseed oil in drums.....	45	4	180	200 to 300
White lead paste in cans..	174	3½	610	
Dry goods:				
Cotton sheeting, in cases..	23	8	184	200 to
Wool, in bales, com-pressed.....	48	-----	-----	250
Groceries:				
Canned goods in cases....	58	6	348	250
Coffee, roasted, in bags....	33	8	264	to
Sugar, in cases.....	51	6	306	300
Hardware:				
Chain.....	100	6	600	300
Wire, insulated copper, in coils.....	63	5	315	to
Wire, galvanized iron, in coils.....	74	4½	333	400
Miscellaneous:				
Tires.....	30	6	180	-----
Books (solidly packed)....	65	6	390	-----
Paper (newspapers).....	35	6	210	-----
Rope, in coils.....	32	6	192	-----
Rubber, crude.....	50	8	400	-----
Chinaware, in crates.....	40	8	320	-----

¹ See par. 219 also. (Reprinted from "Steel Construction" by permission of American Institute of Steel Construction, copyright 1947.)

- (2) In buildings designed for live loads of more than 100 pounds per square foot, no reductions are made except that live loads on columns may be reduced 20 percent.

142. Roof Live Loads

For buildings in locations with climates similar to those of the three zones into which the United States has been divided for this purpose, roof live loads in pounds per square foot of horizontal projection are given in figure 69.

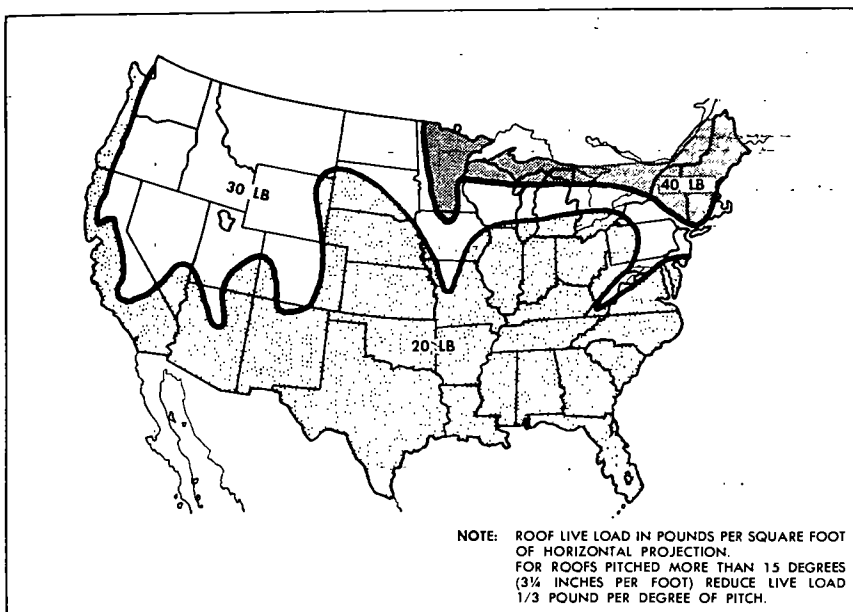


Figure 69. Roof live loads in the United States.

143. Wind Loads

a. Bridges. Short bridges are designed with no allowance for wind. For bridges of 100-foot span or more, the following wind loads are used in design:

- (1) With no live load on bridge, 30 pounds per square foot on 1.5 times the net area of the side elevation.
- (2) With full live load, change the above 30 pounds to 15 pounds per square foot on 1.5 times the net area of bridge and load, and increase the allowable live-load stress by 5 percent.

b. Buildings. The wind pressure and suction (uplift) loads normally used in design, in pounds per square foot of vertical projection, are given in table 147. Wind pressure and suction both act in a direction normal to the plane of a wall or roof. Wind-load requirements are developed locally for areas subject to hurricanes or other violent winds.

c. Stress Increases for Wind Loads. See paragraph 149 for modifications in unit stresses in structural steel, for wind loads alone.

144. Impact Loads

No allowance for impact is required for any wood structures, and normally none is required in any other structures except those designed to carry heavy, moving loads. In steel-bridge structures, live-load stresses are modified for impact and similar factors, as follows:

Table 147. Wind Pressures on Buildings

Surface				Load in pounds per square foot of vertical projection		
				Pressure	Suction	
Exterior walls.	Temporary buildings not used for assembly-----			10	-----	
	Permanent buildings-----			20	-----	
Additional load on interior side of exterior walls.	Buildings nominally tight-----			4. 5 or	4. 5	
	Buildings between tight and 30 percent open-----			4. 5 to '12 or 4. 5 to '19		
	Buildings 30 percent or more open-----			12 or	19	
Chimneys	Square or rectangular-----			30	-----	
	Hexagonal or octagonal-----			24	-----	
	Round or elliptical-----			18	-----	
Flat roofs.					12	
Pitched roofs.	Windward side.	Roofs pitched under 20°-----			12	
		Roofs pitched 20° to 30°-----			12 to '0	
		Roofs pitched 30° to 60°-----		0 to '9	-----	
		Roofs pitched 60° and over-----		9	-----	
	Leeward side, all pitches-----				9	
Bowstring roofs.	Starting at ground level.	Windward ¼ of arc-----	0. 0 to 0. 6	0 to '11. 4	-----	
		Central ½ of arc-----	any		11	
		Leeward ¼ of arc-----	any		9	
	On elevated supports.	Windward ¼ of arc-----	0. 0 to 0. 2	0 to '12 (or)	12	
			0. 2 to 0. 6		12 to '0	
			0. 2 to 0. 35		11 to '20	
		Central ½ of arc-----	0. 0 to 0. 6		9	
			Leeward ¼ of arc-----	any		
				Ratio— Rise: Run	Pressure	Suction

' Uniform rate of increase or decrease.

a. Highway Bridges. For impact, increase stresses by 15 percent of the live-load stress in steel superstructures. No increase is required in substructures.

b. Railroad Bridges. No allowance for impact is required for substructures other than steel towers. For rolling effect in superstructures and steel towers increase stresses 20 percent in the loading from one rail and provide an equal decrease in the loading from the other rail. In addition, for impact, live-load stresses are increased by percentages as follows:

(1) For steam locomotives:

$$(a) \text{ Spans under 100 feet, } I=80-\frac{L^2}{500}$$

$$(b) \text{ Spans over 100 feet, } I=\frac{1800}{L-40}+30$$

(2) For electric locomotives,

$I = \frac{360}{L} + 12.5$. Where I = percentage of live-load stress added for impact and L is span in feet for stringers, floor-beams (this length also applies for subdiagonals of trusses), longitudinal girders, and trusses (for chords and main members).

145. Combined Loads

Structures are designed for combinations of dead, live, and other loads given above, at working stresses authorized for the materials used. For combined loads including wind loads, working stresses for certain materials are increased to higher values authorized under those conditions (par. 149) provided the resulting section is adequate for all loads except wind, at normal working stresses.

Section II. DESIGN FORMULAS

146. Formulas For Beam Design

The formulas given apply primarily to vertical shear, bending moments, and deflections. They are useful as reference material in the design of simple beams but the designer considers also the effects of horizontal shear, moving loads, impact, and the like. For additional information see standard handbooks in unit libraries.

a. List of symbols.

A = area of cross section in square inches

b = breadth or width in inches

c = distance, neutral axis to extreme fiber in inches

d = depth in inches

Δ = deflection

E = modulus of elasticity

f = unit stress in p.s.i.

f_h = horizontal shear in p.s.i.

I = moment of inertia

L = span in feet

l = span in inches

M = moment, bending moment

P = concentrated load

p = pressure per unit of area

R = reaction

r = radius of gyration

S = section modulus = $\frac{I}{c}$

V = total vertical shear

v = unit vertical shear

W = total load on one span

w = load per unit of length

X = horizontal axis

x = distance parallel to X axis

Y = vertical axis

y = distance parallel to Y axis

b. *Properties of Sections.* Areas, moments of inertia, and other properties of selected geometrical shapes are given in figure 70.

c. *Beam Formulas for Flexural Stress at Extreme Fiber.*

$$f = \frac{Mc}{I} = \frac{M}{S}$$

$$M = \frac{If}{c} = Sf$$

$$S = \frac{I}{c} = \frac{M}{f}$$

d. *Horizontal Shear Stresses in Beams.*

(1) Rectangular beams.

$$f_h = \frac{3}{2} \times \frac{V}{bd}$$

(2) Steel I beams.

$$f_h = \frac{V}{\text{web thickness} \times \text{depth between curved fillets}}$$

(3) Beams of circular cross section.

$$f_h = \frac{16V}{3\pi d^2}$$

e. Reactions, moments, and shears for statically loaded beams are given in figure 71.

Beams Without Lateral Support. Long unsupported or unbraced beams having $\frac{l}{b}$ value greater than 40 are not normally used as load carrying members. These beams should be braced or supported to reduce the value of $\frac{l}{b}$. For investigation of beams where adequate lateral support is not provided, a reduced extreme fiber stress in bending is computed from the following:

$$f = \frac{14,400,000}{ld \div bt}$$

Where f = allowable stress in psi

l = unsupported length in inches

b = flange width in inches

t = flange thickness in inches

f. *Continuous Beams.* For continuous beams with equal spans and uniformly distributed loads, two to five spans, moment and shear coefficients are given in figure 72.

147. Stresses in Rigid Frames

Stresses in rigid frames, for various conditions of static loading, are given in figure 73.

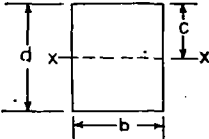
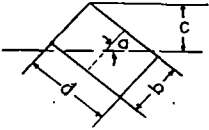
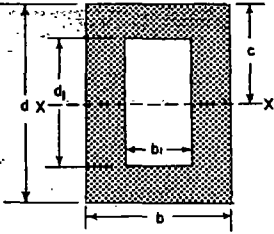
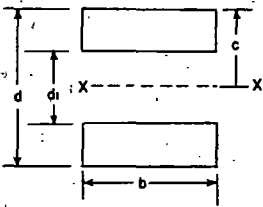
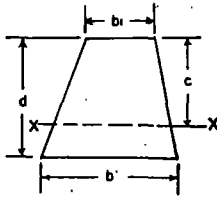
Rectangle Axis of moments through center 	$A = bd$ $c = \frac{d}{2}$ $I = \frac{bd^3}{12} \quad f_h = \frac{3}{2} \frac{V}{bd}$ $S = \frac{bd^2}{6}$ $r = \frac{d}{\sqrt{12}} = .288675 d$
Rectangle Axis of moments any line through center of gravity 	$A = bd$ $c = \frac{b \sin \alpha + d \cos \alpha}{2}$ $I = \frac{bd (b^2 \sin^2 \alpha + d^2 \cos^2 \alpha)}{12}$ $S = \frac{bd (b^2 \sin^2 \alpha + d^2 \cos^2 \alpha)}{6 (b \sin \alpha + d \cos \alpha)}$ $r = \sqrt{\frac{b^2 \sin^2 \alpha + d^2 \cos^2 \alpha}{12}}$
Hollow Rectangle Axis of moments through center 	$A = bd - b_1 d_1$ $c = \frac{d}{2}$ $I = \frac{bd^3 - b_1 d_1^3}{12}$ $S = \frac{bd^2 - b_1 d_1^2}{6d}$ $r = \sqrt{\frac{bd^3 - b_1 d_1^3}{12A}}$
Equal Rectangles Axis through center of gravity 	$A = b (d - d_1)$ $c = \frac{d}{2}$ $I = \frac{b (d^3 - d_1^3)}{12}$ $S = \frac{b (d^2 - d_1^2)}{6d}$ $r = \sqrt{\frac{d^3 - d_1^3}{12 (d - d_1)}}$
Trapezoid Axis of moments through center of gravity 	$A = \frac{d (b + b_1)}{2}$ $c = \frac{d (2b + b_1)}{3 (b + b_1)}$ $I = \frac{d^3 (b^2 + 4bb_1 + b_1^2)}{36 (b + b_1)}$ $S = \frac{d^2 (b^2 + 4bb_1 + b_1^2)}{12 (2b + b_1)}$ $r = \frac{d}{6 (b + b_1)} \sqrt{2 (b^2 + 4bb_1 + b_1^2)}$

Figure 70. Properties of sections.

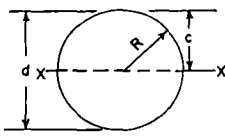
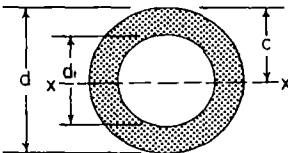
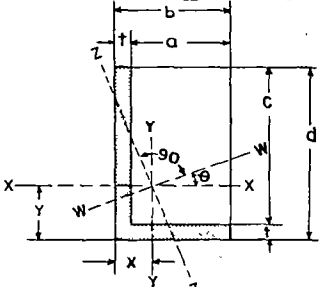
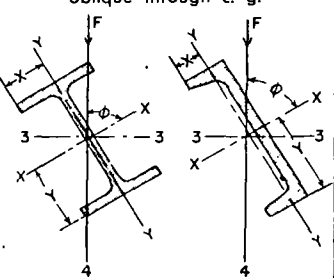
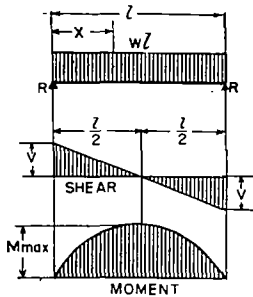
Circle Axis through center 	$A = \frac{\pi d^2}{4} = \pi R^2 = .785398 d^2 = 3.141593 R^2$ $c = \frac{d}{2} = R$ $I = \frac{\pi d^4}{64} = \frac{\pi R^4}{4} = .049087 d^4 = .785398 R^4$ $S = \frac{\pi d^3}{32} = \frac{\pi R^3}{4} = .098175 d^3 = .785398 R^3$ $r = \frac{d}{4} = \frac{R}{2} \qquad f_h = \frac{16V}{3\pi d^2}$
Hollow Circle Axis through center 	$A = \frac{\pi(d^2 - d_1^2)}{4} = .785398 (d^2 - d_1^2)$ $c = \frac{d}{2}$ $I = \frac{\pi(d^4 - d_1^4)}{64} = .049087 (d^4 - d_1^4)$ $S = \frac{\pi(d^3 - d_1^3)}{32d} = .098175 \frac{d^3 - d_1^3}{d}$ $r = \frac{\sqrt{d^2 + d_1^2}}{4}$
Angle Axis through center of gravity 	$A = t(b + c) \quad x = \frac{b^2 + ct}{2(b + c)} \quad y = \frac{d^2 + ct}{2(b + c)}$ $I_x = \frac{1}{3} [t(d-y)^2 + by^2 - o(y-t)^2]$ $I_y = \frac{1}{3} [t(b-x)^2 + dx^2 - c(x-t)^2]$ $I_x = I_x \sin^2 \theta + I_y \cos^2 \theta + K \sin 2\theta$ $I_y = I_x \cos^2 \theta + I_y \sin^2 \theta - K \sin 2\theta$ $K = \frac{abcdt}{4(b + c)} \quad K \text{ is negative when heel of angle, with reference to c. g., is in 1st or 3rd quadrant, positive when in 2d or 4th.}$
Beams and Channels Transverse force oblique through c. g. 	$I_s = I_x \sin^2 \phi + I_y \cos^2 \phi$ $I_u = I_x \cos^2 \phi + I_y \sin^2 \phi$ $f = M \left(\frac{Y}{I_x} \sin \phi + \frac{X}{I_y} \cos \phi \right)$ Where M is bending moment due to force F

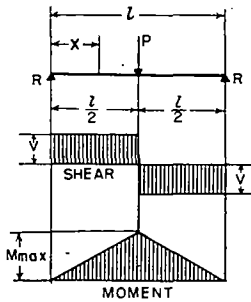
Figure 70—Continued.

Simple beam, uniformly distributed load.



$$\begin{aligned}
 \text{Equivalent uniformly distributed load} &= wl \\
 R = V &= \frac{wl}{2} \\
 V_x &= w \left(\frac{l}{2} - x \right) \\
 M_{\max} \text{ (at center)} &= \frac{wl^2}{8} \\
 M_x &= \frac{wx}{2} (l - x) \\
 \Delta_{\max} \text{ (at center)} &= \frac{5wl^4}{384EI} \\
 \Delta_x &= \frac{wx}{24EI} (l^3 - 2lx^2 + x^3)
 \end{aligned}$$

Simple beam, concentrated load at center



$$\begin{aligned}
 \text{Equivalent uniformly distributed load} &= 2P \\
 R = V &= \frac{P}{2} \\
 M_{\max} \text{ (at point of load)} &= \frac{Pl}{4} \\
 M_x \text{ (when } x < \frac{l}{2}) &= \frac{Px}{2} \\
 \Delta_{\max} \text{ (at point of load)} &= \frac{Pl^3}{48EI} \\
 \Delta_x \text{ (when } x < \frac{l}{2}) &= \frac{Px}{48EI} (3l^2 - 4x^2)
 \end{aligned}$$

Simple beam, concentrated load at any point

Equivalent uniformly distributed load

$$= \frac{8Pab}{l^2}$$

$R_1 = V_1$ (max when $a < b$)

$$= \frac{Pb}{l}$$

$R_2 = V_2$ (max when $a > b$)

$$= \frac{Pa}{l}$$

$M_{\max}$ (at point of load)

$$= \frac{Pab}{l}$$

M_x (when $x < a$)

$$= \frac{Pbx}{l}$$

$\Delta_{\max}$ (at $x = \sqrt{\frac{a(a+2b)}{3}}$ when $a > b$)

$$= \frac{Pab(a+2b)}{27EI} \sqrt{3a(a+2b)}$$

Δ_a (at point of load)

$$= \frac{Pa^2b^2}{3EI}$$

Δ_x (when $x < a$)

$$= \frac{Pbx}{6EI} (l^2 - b^2 - x^2)$$

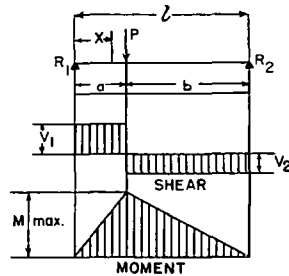


Figure 71. Beam formulas for static loading.

Beam fixed at one end, supported at other

Equivalent uniformly distributed load

$$R_1 = V_1$$

$$R_2 = V_2 \text{ max}$$

$$V_x$$

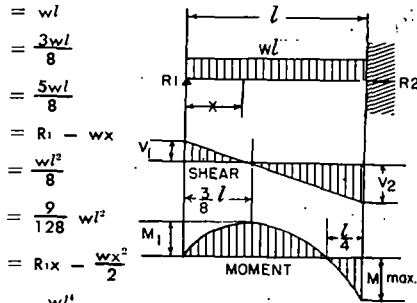
$$M_{\text{max}}$$

$$M_1 \text{ (at } x = \frac{3}{8}l)$$

$$M_x$$

$$\Delta_{\text{max}} \left[\text{at } x = \frac{l}{16} (1 + \sqrt{33}) = .4215l \right] = \frac{wl^4}{185EI}$$

$$\Delta x$$



$$= wl$$

$$= \frac{3wl}{8}$$

$$= \frac{5wl}{8}$$

$$= R_1 - wx$$

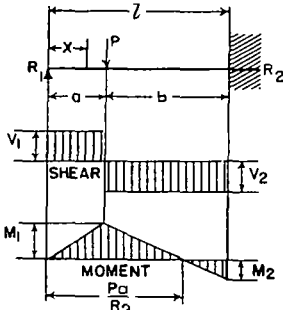
$$= \frac{wl^2}{8}$$

$$= \frac{9}{128} wl^2$$

$$= R_1 x - \frac{wx^2}{2}$$

$$= \frac{wx}{48EI} (l^3 - 3lx^2 + 2x^3)$$

Beam fixed at one end, supported at other, concentrated load at any point



$$\Delta_{\text{max}} \text{ (when } a < .414l \text{ at } x = l \frac{l^2 + a^2}{3l^2 - a^2})$$

$$\Delta_{\text{max}} \text{ (when } a > .414l \text{ at } x = l \sqrt{\frac{a}{2l + a}})$$

$$\Delta a \text{ (at point of load)}$$

$$\Delta x \text{ (when } x < a)$$

$$\Delta x \text{ (when } x > a)$$

$$R_1 = V_1 = \frac{Pb^2}{2l^2} (a + 2l)$$

$$R_2 = V_2 = \frac{Pa}{2l^2} (3l^2 - a^2)$$

$$M_1 \text{ (at point of load)} = R_1 a$$

$$M_2 \text{ (at fixed end)} = \frac{Pab}{2l^2} (a + l)$$

$$M_x \text{ (when } x < a) = R_1 x$$

$$M_x \text{ (when } x > a) = R_1 x - P(x - a)$$

$$= \frac{Pa}{3EI} \frac{(l^2 - a^2)^3}{(3l^2 - a^2)^2}$$

$$= \frac{Pab^2}{6EI} \sqrt{\frac{a}{2l + a}}$$

$$= \frac{Pa^2 b^3}{12EI l^4} (3l + a)$$

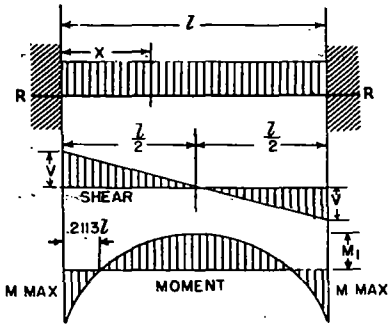
$$= \frac{Pb^2 x}{12EI l^4} (3al^2 - 2lx^2 - ax^2)$$

$$= \frac{Pa}{12EI l^4} (l - x)^2 (3l^2 x - a^2 x - 2a^2 l)$$

Figure 71—Continued.

Beam fixed at both ends, uniformly distributed load.

$$\text{Equivalent uniform load (as a simple beam)} = \frac{2wl}{3}$$



$$R = V = \frac{wl}{2}$$

$$V_x = w \left(\frac{l}{2} - x \right)$$

$$M_{\text{max}} (\text{at ends}) = \frac{wl^2}{12}$$

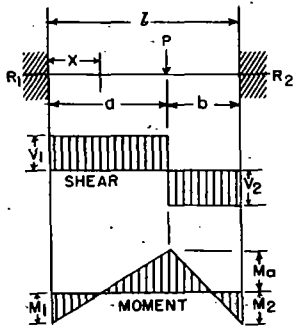
$$M_1 (\text{at center}) = \frac{wl^2}{24}$$

$$M_x = \frac{w}{12} (6lx - l^2 - 6x^2)$$

$$\Delta_{\text{max}} (\text{at center}) = \frac{wl^4}{384EI}$$

$$\Delta x = \frac{wx^3}{24EI} (l - x)^2$$

Beam fixed at both ends, concentrated load at any point.



$$R_1 = V_1 (\text{max when } a < b) = \frac{Pb^2}{l^2} (3a + b)$$

$$R_2 = V_2 (\text{max when } a > b) = \frac{Pa^2}{l^2} (a + 3b)$$

$$M_1 (\text{max when } a < b) = \frac{Pab^2}{l^2}$$

$$M_2 (\text{max when } a > b) = \frac{Pa^2b}{l^2}$$

$$M_a (\text{at point of load}) = \frac{2Pa^2b^2}{l^3}$$

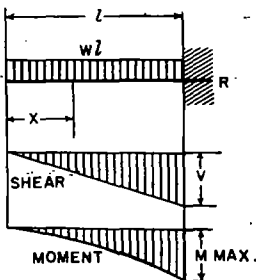
$$M_x (\text{when } x < a) = R_1x - \frac{Pab^2}{l^2}$$

$$\Delta_{\text{max}} (\text{when } a > b \text{ at } x = \frac{2a}{3a + b}) = \frac{2Pa^3b^2}{3EI(3a + b)^2}$$

$$\Delta a (\text{at point of load}) = \frac{Pa^2b^3}{3EI l^3}$$

$$\Delta x (\text{when } x < a) = \frac{Pb^2x^2}{6EI l^2} (3al - 3ax - bx)$$

Cantilever beam; uniformly distributed load.



$$\text{Equivalent uniform load (as a simple beam)} = 4wl$$

$$R = V = wl$$

$$V_x = wx$$

$$M_{\text{max}} (\text{at fixed end}) = \frac{wl^2}{2}$$

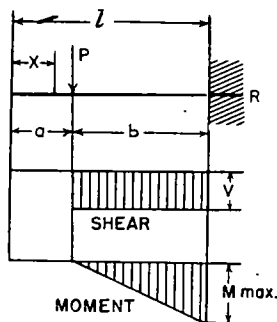
$$M_x = \frac{wx^2}{2}$$

$$\Delta_{\text{max}} (\text{at free end}) = \frac{wl^4}{8EI}$$

$$\Delta x = \frac{w}{24EI} (x^4 - 4l^3x + 3l^4)$$

Figure 71—Continued.

Cantilever beam, concentrated load at any point



Equivalent uniform load (as a simple beam) $= \frac{8Pb}{l}$

$R = V$ (when $x < a$) $= P$

$M_{\max}$ (at fixed end) $= Pb$

M_x (when $x > a$) $= P(x - a)$

$\Delta_{\max}$ (at free end) $= \frac{Pb^2}{6EI} (3l - b)$

Δ_a (at point of load) $= \frac{Pb^3}{3EI}$

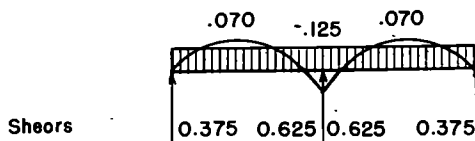
Δ_x (when $x < a$) $= \frac{Pb^2}{6EI} (3l - 3x - b)$

Δ_x (when $x > a$) $= \frac{P(l-x)^2}{6EI} (3b - l + x)$

Figure 71.—Continued

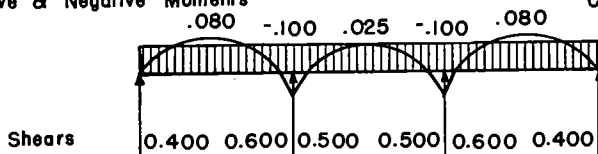
Positive and Negative Moments

Coefficients of wl^2



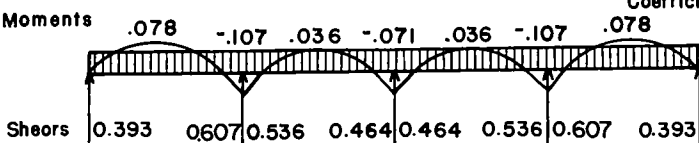
Positive & Negative Moments

Coefficients of wl^2



Moments

Coefficients of wl^2



Moments

Coefficients of wl^2

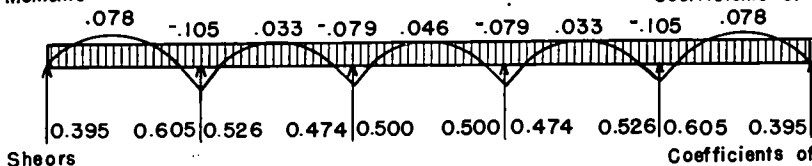
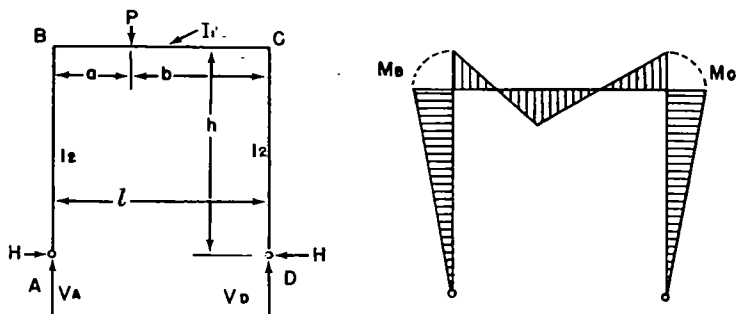


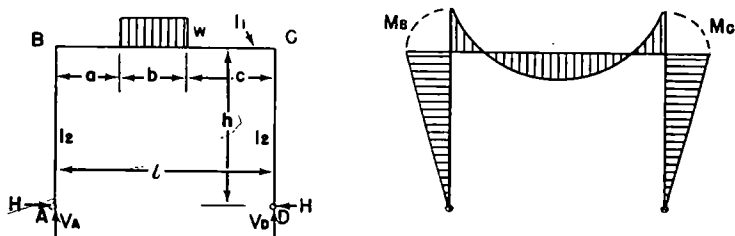
Figure 72. Moments and shears in continuous beams.

Concentrated vertical load.



General Case	Load in Center $a = b$
$H = \frac{3Pab}{2h(2k + 3)} ; k = \frac{I_1}{I_2} \cdot \frac{h}{l}$	$H = \frac{3Pl}{8h(2k + 3)} ; k = \frac{I_1}{I_2} \cdot \frac{h}{l}$
$V_A = \frac{Pb}{l} \quad V_D = \frac{Pa}{l}$	$V_A = \frac{P}{2} \quad V_D = \frac{P}{2}$
$M_B = M_C = -Hh$	$M_B = M_C = -Hh$

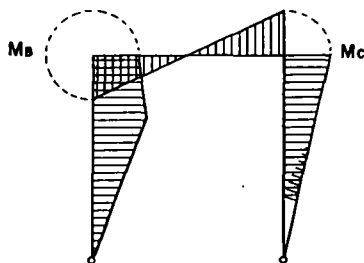
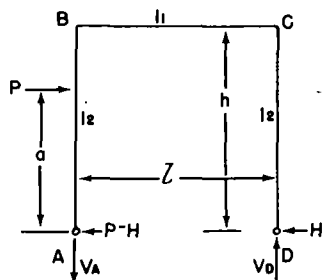
Uniformly distributed vertical load.



General Case	Top Fully Loaded $b = l$
$H = \frac{wb}{4} \cdot \frac{6ac + b(3l + 2b)}{h(2k + 3)} ; k = \frac{I_1}{I_2} \cdot \frac{h}{l}$	$H = \frac{wl}{4h(2k + 3)} ; k = \frac{I_1}{I_2} \cdot \frac{h}{l}$
$V_A = \frac{wb}{2l} (2c + b) ; V_D = \frac{wb}{2l} (2a + b)$	$V_A = V_D = \frac{wl}{2}$
$M_B = M_C = -Hh$	$M_B = M_C = -Hh$

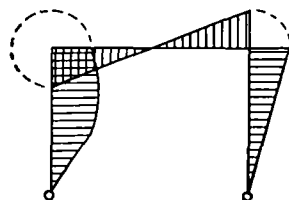
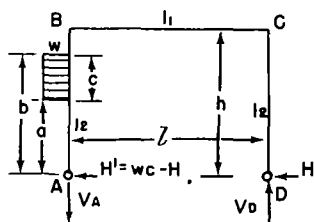
Figure 73. Stresses in rigid frames.

Concentrated horizontal load.



General Case	Load at B $a = h$
$H = \frac{Pa}{2} \cdot \frac{3h^2 + k(3h^2 - a^2)}{h(2k + 3)} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$	$H = \frac{P}{2}$
$V_A = V_D = \frac{Pa}{l}$	$V_A = V_D = \frac{Ph}{l}$
$M_B = Pa - Hh; M_C = -Hh$	$M_B = +\frac{1}{2}Ph; M_C = -\frac{1}{2}Ph$

Uniformly distributed horizontal load.



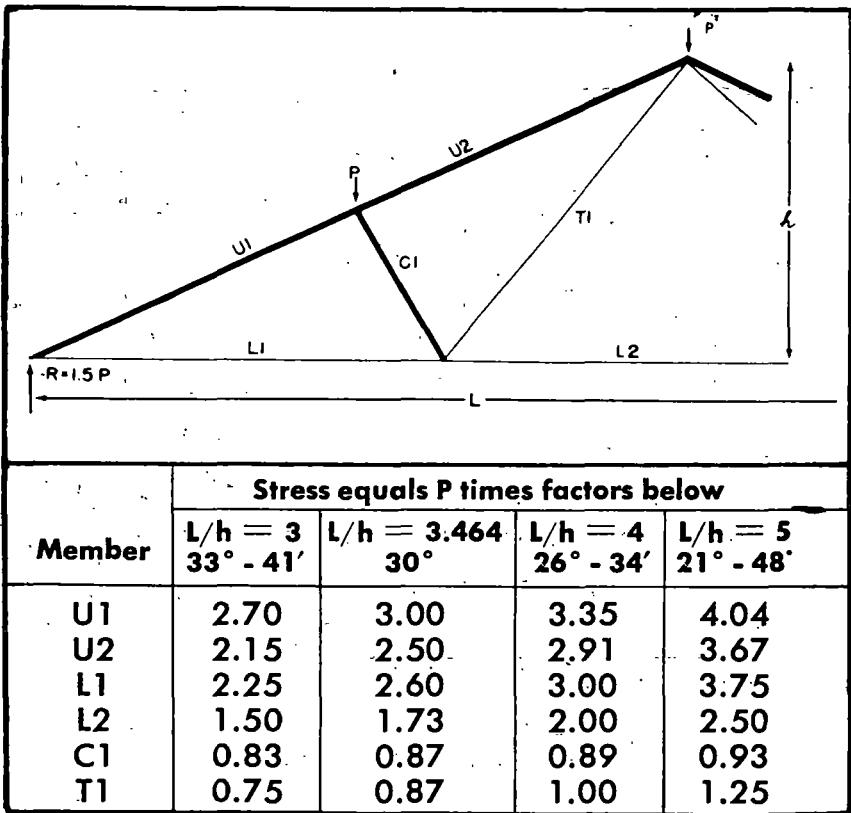
General Case	Side Fully Loaded; $c = h$
$H = \frac{w}{8h} \cdot \frac{[6h^2(l+k)(b^2 - a^2) - k(b^4 - a^4)]}{2k + 3}$	$H = \frac{wh}{8} \cdot \frac{6 + 5h}{2k + 3}$
$V_A = V_D = \frac{w(b^2 - a^2)}{2l} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$	$V_A = V_D = \frac{wh^2}{2l} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$
$M_B = V_A l - Hh; M_C = -Hh$	$M_B = V_A l - Hh; M_C = -Hh$

Figure 73—Continued.

148. Stresses in Truss Members

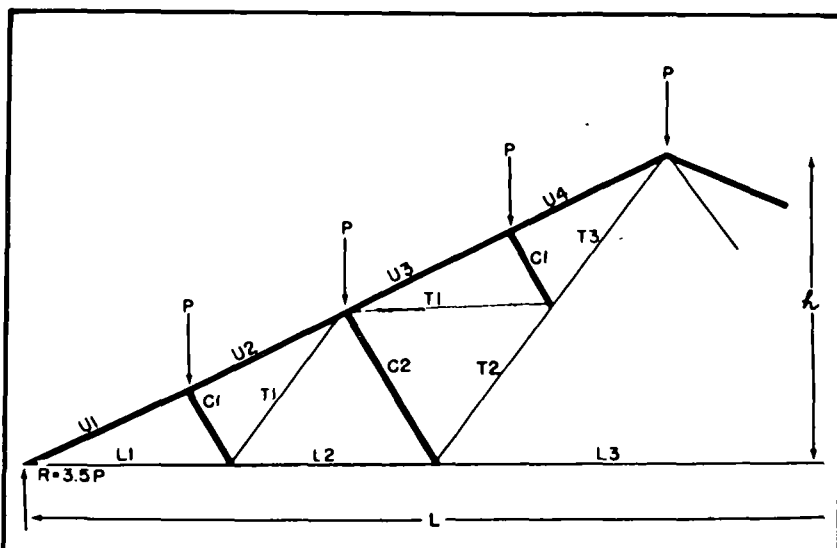
a. Stresses in truss members are found by methods given in standard handbooks in unit libraries. For common types of trusses, stress factors based on symmetrical vertical loads only, and based on equal panel lengths and panel loads, are given in figure 74. In the truss diagrams shown, compression members are indicated by heavy lines, tension members by light lines.

b. Cooper's E-45 loading (fig. 68) produces for each rail the moments, shears, and pier reactions shown in table 148. The values for any other Cooper's loading are directly proportional to those tabulated for Cooper's E-45; e.g., for E-30, multiply the tabulated values by 30/45. The values are adjusted for dead loads and for wind, impact, and other loads as required by paragraphs 141, 143, and 144.



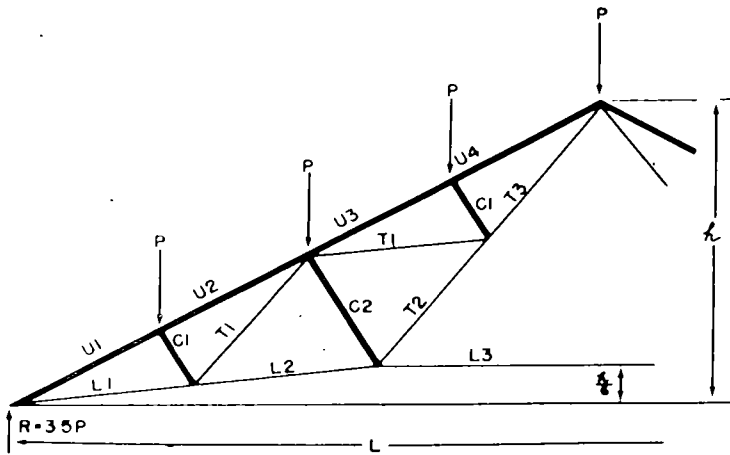
① Four-panel Fink truss

Figure 74. Stresses in truss members.



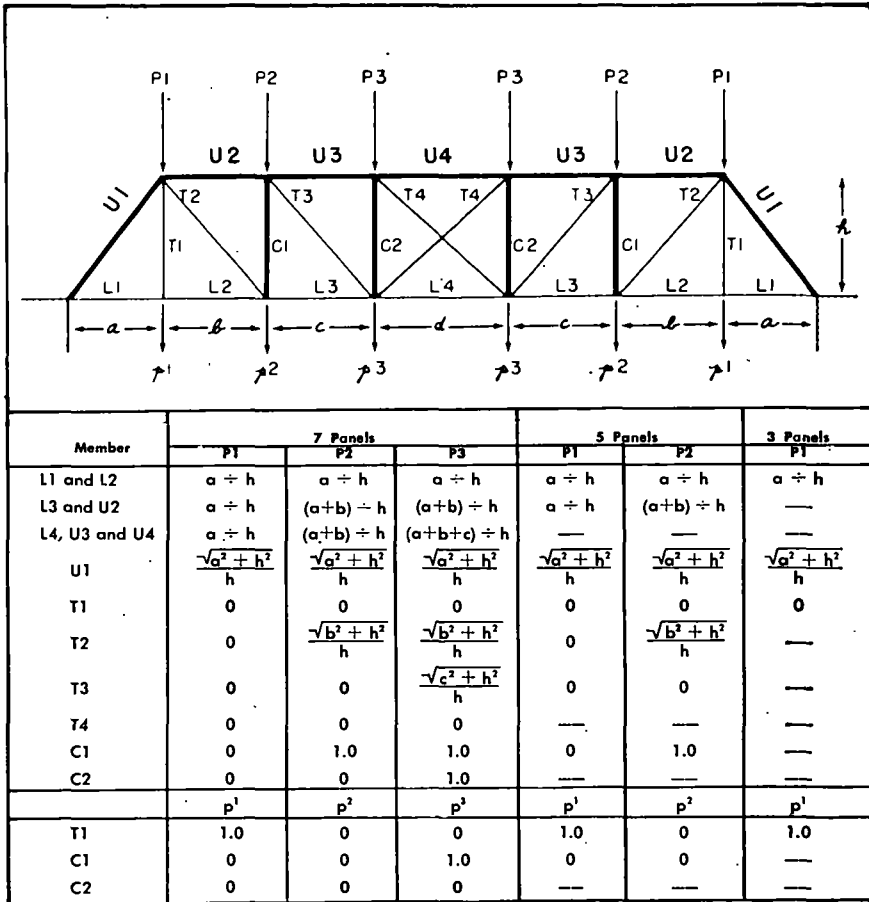
Member	Stress equals P times factors below				
	$L/h = 3$ 33° - 41'	$L/h = 3.464$ 30°	$L/h = 4$ 26° - 34'	$L/h = 5$ 21° - 48'	$L/h = 6$ 18° - 26'
U1	6.31	7.00	7.83	9.42	11.07
U2	5.75	6.50	7.38	9.05	10.75
U3	5.20	6.00	6.93	8.68	10.43
U4	4.65	5.50	6.48	8.31	10.12
L1	5.25	6.06	7.00	8.75	10.50
L2	4.50	5.19	6.00	7.50	9.00
L3	3.00	3.46	4.00	5.00	6.00
C1	0.83	0.87	0.89	0.93	0.95
C2	1.66	1.73	1.79	1.86	1.90
T1	0.75	0.87	1.00	1.25	1.50
T2	1.50	1.73	2.00	2.50	3.00
T3	2.25	2.60	3.00	3.75	4.50

Figure 74—Continued.



Member	Stress equals P times factors below			
	$L/h = 3$ 33° - 41'	$L/h = 3.464$ 30°	$L/h = 4$ 26° - 34'	$L/h = 5$ 21° - 48'
U1	8.49	9.63	10.96	13.49
U2	7.94	9.13	10.51	13.11
U3	7.39	8.63	10.06	12.74
U4	6.83	8.13	9.61	12.37
L1	7.17	8.44	9.90	12.61
L2	6.15	7.23	8.48	10.81
L3	3.60	4.16	4.80	6.00
C1	0.83	0.87	0.89	0.93
C2	1.66	1.73	1.79	1.86
T1	1.02	1.21	1.41	1.80
T2	2.87	3.37	3.96	5.04
T3	3.89	4.58	5.37	6.85

Figure 74—Continued.



NOTES: For loads p^1, p^2 , etc., the coefficients for the chords and diagonals are the same as given for the loads P_1, P_2 , etc. The coefficients for the verticals for loads p^1, p^2 , etc., are given in the supplementary table below the general table.

Figure 74—Continued.

Table 148. Moments, Shears, Pier Reactions for Cooper's E-45 Loading

Span (feet)	Maximum moment (M) (kips- foot)	Maximum shear (V)			Maximum pier reaction (R) (kips)	Equivalent uniform load		
		End (kips)	Quarter- point (kips)	Center (kips)		For maximum moment (pound- foot)	For maximum end shear (pound- foot)	For maximum pier reaction (pound- foot)
10	63.4	33.8	22.5	11.3	45.0	5,063	6,750	4,500
11	73.0	36.8	23.5	12.2	49.1	4,887	6,705	4,464
12	90.0	39.4	24.4	13.1	52.6	5,004	6,561	4,374
13	106.9	41.6	25.1	13.0	55.4	5,063	6,390	4,266
14	123.8	43.4	26.6	14.6	58.7	5,049	6,210	4,194
15	140.7	45.0	28.2	14.9	61.5	5,004	6,003	4,100
16	157.5	57.8	29.6	15.4	64.0	4,923	5,976	4,001
17	174.4	50.3	30.9	15.6	66.2	4,824	5,922	3,893
18	191.3	52.5	31.9	15.7	68.3	4,725	5,841	3,789
19	210.0	54.5	32.9	15.8	70.7	4,653	5,733	3,726
20	233.0	56.3	33.8	15.8	73.7	4,644	5,625	3,670
21	254.3	57.8	35.3	16.3	76.4	4,590	5,613	3,636
22	276.4	59.3	36.8	16.9	79.8	4,545	5,391	3,582
23	298.6	60.7	38.2	17.4	81.2	4,500	5,274	3,528
24	320.9	62.4	39.4	17.8	83.2	4,446	5,198	3,465
25	343.2	63.9	40.5	18.2	85.1	4,392	5,112	3,402
26	365.4	65.3	41.5	18.5	87.4	4,338	5,027	3,362
27	387.7	66.6	42.5	19.0	90.1	4,375	4,932	3,339
28	411.2	68.0	43.4	19.3	92.5	4,221	4,851	3,303
29	436.5	69.2	44.2	19.6	94.9	4,163	4,770	3,272
30	461.7	70.9	45.0	19.9	97.1	4,104	4,730	3,236
31	487.0	72.5	45.8	20.4	99.5	4,050	4,676	3,213
32	512.4	73.9	46.6	21.1	102.3	4,005	4,617	3,200
33	537.7	75.3	47.3	21.6	105.0	3,951	4,563	3,182
34	563.2	76.6	48.2	22.1	107.5	3,897	4,505	3,159
35	588.4	77.9	49.0	22.6	109.8	3,848	4,451	3,137
36	617.2	79.4	49.6	23.2	112.0	3,816	4,410	3,110
37	646.1	80.8	50.4	23.6	114.2	3,780	4,370	3,087
38	675.0	82.3	51.0	23.9	116.7	3,753	4,329	3,069
39	705.0	83.6	51.8	24.4	119.1	3,721	4,288	3,051
40	737.2	84.9	52.7	24.8	121.5	3,690	4,244	3,038
42	802.8	87.8	54.2	25.5	126.2	3,636	4,185	3,006
44	868.1	90.6	55.7	26.1	131.0	3,582	4,122	2,979
46	933.6	93.2	57.1	26.6	135.8	3,537	4,050	2,952
48	998.6	95.7	58.6	27.2	140.4	3,483	3,987	2,925
50	1,069.7	98.1	60.1	28.0	144.9	3,429	3,924	2,898
55	1,256.5	104.2	62.9	29.7	157.9	3,339	3,794	2,876
60	1,462.1	110.3	67.7	31.4	172.4	3,249	3,672	2,876
65	1,684.7	116.7	70.9	33.1	186.0	3,195	3,591	2,862
70	1,921.0	124.3	74.2	34.6	199.2	3,137	3,551	2,844
75	2,166.6	132.4	77.1	36.4	211.7	3,087	3,528	2,822
80	2,432.5	139.8	80.6	37.9	223.7	3,038	3,497	2,799
85	2,707.7	147.1	84.5	39.7	234.7	3,002	3,465	2,763
90	3,004.3	154.4	88.6	41.3	245.9	2,966	3,429	2,732
95	3,306.9	161.6	92.8	42.8	256.6	2,934	3,402	2,700
100	3,622.4	168.8	97.4	44.3	266.9	2,898	3,375	2,669
105	3,979.8	175.6	101.4	45.6	276.8	2,894	3,334	2,637
110	4,372.7	182.3	105.6	47.1	286.7	2,889	3,312	2,606

Table 148. Moments, Shears, Pier Reactions for Cooper's E-45 Loading—Con.

Span (feet)	Maximum moment (<i>M</i>) (kips- foot)	Maximum shear (<i>V</i>)			Maximum pier reaction (<i>R</i>) (kips)	Equivalent uniform load		
		End (kips)	Quarter- point (kips)	Center (kips)		For maximum moment (pound- foot)	For maximum end shear (pound- foot)	For maximum pier reaction (pound- foot)
115	4, 775. 6	188. 9	109. 7	48. 5	296. 1	2, 889	3, 285	2, 574
120	5, 190. 8	195. 4	113. 8	50. 0	306. 0	2, 885	3, 258	2, 552
125	5, 621. 0	201. 8	127. 8	51. 8	316. 1	2, 880	3, 231	2, 529
150	7, 945. 1	233. 3	137. 0	61. 2	366. 0	2, 826	3, 110	2, 439
175	10, 521. 5	263. 8	155. 6	70. 4	418. 1	2, 750	3, 015	2, 390
200	13, 357. 1	293. 7	172. 6	79. 2	471. 4	2, 669	2, 939	2, 358
250	19, 791. 5	362. 4	206. 6	95. 7	579. 6	2, 534	2, 817	2, 318

c. The section modulus may be determined from—

$$S = \frac{M_{tot}}{f}$$

where—

S=section modulus required for stringers under one rail and is measured in inches³.

*M*_{tot}=total maximum bending moment in inch-pounds.

f=allowable bending stress in p.s.i.

Table 149 gives values for *S* for various spans and corresponding values of *M*_{tot}.

Table 149. Section Modulus and Shear

Span (feet)	MTOT (feet K)	SREQ (in S)	Maximum shear (K)	Span (feet)	MTOT (feet K)	SREQ (in S)	Maximum shear (K)
10	202. 1	90	80. 7	37	1462. 5	650	171. 4
11	222. 8	99	85. 4	38	1526. 9	679	174. 4
12	255. 8	114	89. 4	39	1594. 3	709	177. 3
13	290. 0	129	92. 8	40	1663. 2	739	179. 8
14	323. 6	144	95. 7	42	1805. 1	802	186. 1
15	348. 6	155	98. 3	44	1947. 2	865	192. 2
16	393. 5	175	103. 5	46	2097. 8	932	198. 1
17	428. 4	190	108. 0	48	2240. 4	996	203. 7
18	463. 8	206	112. 1	50	2400. 1	1067	208. 8
19	502. 2	223	115. 6	52	2566	1140	213. 9
20	576. 0	256	121. 7	54	2744	1219	220. 1
21	620. 4	275	124. 9	56	2923	1299	225. 7
22	665. 3	295	127. 8	58	3106	1380	231. 1
23	712. 9	316	130. 1	60	3305	1469	236. 8
24	758. 5	336	133. 2	65	3815	1695	251. 9
25	806. 2	358	136. 2	70	4352	1934	268. 3
26	855. 1	380	138. 9	75	4938	2195	285. 9
27	901. 7	401	141. 9	80	5545	2464	301. 8
28	952. 6	423	144. 5	85	6167	2741	317. 6
29	1005. 9	447	146. 5	90	6856	3047	333. 1
30	1060. 7	471	150. 4	95	7544	3353	348. 1

Table 149. Section Modulus and Shear—Continued

Span (feet)	MTOT (feet +)	SREQ (in S)	Maximum shear (+)	Span (feet)	MTOT (feet +)	SREQ (in S)	Maximum shear (+)
31-----	1113. 8	495	153. 5	100----	8283	3681	362. 9
32-----	1168. 3	519	156. 5	105----	9095	4042	377. 5
33-----	1225. 2	544	159. 5	110----	9975	4433	392. 0
34-----	1279. 9	569	162. 3	115----	10886	4838	406. 9
35-----	1337. 1	594	165. 0	120----	11817	5252	421. 4
36-----	1400. 6	622	168. 2	125----	12813	5695	436. 5

Section III. STRUCTURAL STEEL

149. Working Stresses

a. Basic Stresses. For permanent construction, the allowable unit stresses are given in the Manual of the American Institute of Steel Construction. For temporary buildings and for military construction in a theater of operations, the allowable unit stresses in structural steel, rivets, bolts, and welds are as follows (except as modified by *b* below, and unless modifications are required due to the use of steel of specifications which differ from those in the manual referred to above).

- | | |
|---|---|
| | <i>Pounds
per
square
inch</i> |
| (1) <i>Tension.</i> | |
| (a) Structural steel, net section----- | 27, 000 |
| (b) Bolts at root of thread----- | 20, 000 |
| (c) Butt welds, section through throat----- | 20, 000 |
| (2) <i>Compression.</i> | <i>Pounds per square inch</i> |
| (a) Plate girders stiffeners, gross section---- | 27, 000 |
| (b) Columns, axial compression, gross sec- | |
| tion, for values of $\frac{l}{r}$ not over 140: | |
| Riveted ends----- | $21,300 - \frac{3}{8} \left(\frac{l}{r} \right)^2$ |
| Pinned ends----- | $21,300 - \frac{1}{2} \left(\frac{l}{r} \right)^2$ |
| Where l = unsupported lengths in inches | |
| r = least radius of gyration in inches | |
| (c) Butt welds, section through throat (crush- | |
| ing)----- | 24,000 |
| (3) <i>Bending.</i> | <i>Pounds per square inch</i> |
| (a) Tension on extreme fibers of rolled sec- | |
| tions, plate girders, and built-up mem- | |
| bers----- | 27,000 |

- (b) Compression on extreme fibers of rolled sections, plate girders, and built-up members:

For $\frac{1}{b}$ less than 15 ----- 27,000

For $\frac{1}{b}$ values between 15 and 40 ----- $27,000 - \frac{15}{2} \left(\frac{1}{b} \right)^2$

Where l = laterally unsupported length
in inches

b = flange width in inches

- (c) Butt welds. Stresses due to bending shall not exceed those prescribed above for tension and compression, respectively.

	Pounds per square inch
(4) <i>Shear.</i>	
(a) Rivets and pins -----	20,000
(b) Girder web, gross section -----	16,500
(c) Turned bolts in reamed holes -----	16,500
(d) Unfinished bolts -----	12,000
(e) Weld metal, on section through throat of fillet weld or on faying surface area of plug or slot weld ----	15,000

Note. Stress in a fillet weld shall be considered as shear on the throat, for any direction of the applied stress. Neither filled nor fillet-welded plug or slot welds shall be assigned any values in resistance to stress other than shear.

	Pounds per square inch	
	Double shear	Single shear
(5) <i>Bearing.</i>		
(a) Rivets -----	40,000	32,000
(b) Turned bolts in reamed or drilled holes -----	40,000	32,000
(c) Pins -----		32,000
(d) Contact area:		
1. Milled stiffeners and other milled surfaces -----		30,000
2. Fitted stiffeners -----		27,000
(e) Expansion rollers or rockers (pounds per linear inch) in which d is diameter of roller or rocker in inches -----		600d

b. Stresses for Wind Loads. All allowable stresses given in *a* above are increased 30 percent but not to exceed 27,000 pounds per square inch, for members subject to wind loads, provided the sections thus determined are adequate at normal stresses for all loads except wind, and including impact (if any).

	Pounds per square inch
<i>c. Bearing on Masonry.</i>	
(1) Granite -----	800
(2) Sandstone and limestone -----	400
(3) Portland-cement concrete -----	600
(4) Hard brick in cement mortar -----	250

d. Stresses in Web Crippling. To avoid web crippling, beams are designed so the compression stress in the web at the toe of the fillet, resulting from reactions or concentrated loads, shall not exceed 24,000 pounds per square inch. These stresses are figured as follows, for webs without stiffeners:

$$\text{Maximum end reaction in kips} = 24t(a + k)$$

$$\text{Maximum interior load in kips} = 24t(a' + 2k)$$

Where t = web thickness in inches

k = distance from outer face of flange to toe of fillet, in inches

a' = length of concentrated load bearing, in inches

Where the above values are exceeded, either the webs of the beams are reinforced with stiffener angles or the bearing area is increased.

e. Beams Without Lateral Support. A beam is considered to have adequate lateral support if its top flange is embedded about 1 inch in a concrete slab extending over the beams of a floor system. A beam

not thus supported carries its full load if its value for $\frac{ld}{bt}$, an expression

used in the formula below, does not exceed 400; or if it is braced adequately with steel struts at intervals as required to keep the value less than 400. If adequate lateral support is not provided, a reduced extreme fiber stress in bending is computed from the following:

$$\text{for } \frac{ld}{bt} \text{ values between 400 and 1000, } f = 34,000 - 17.7 \left(\frac{ld}{bt} \right)$$

$$\text{for } \frac{ld}{bt} \text{ values above 1000, } f = \frac{16,400,000}{\frac{ld}{bt}}$$

Where f = allowable stress in pounds per square inch

l = unsupported length in inches

d = depth of beam in inches

b = flange width in inches

t = flange thickness in inches

150. Weights and Areas of Bars and Plates

Table 150. Weights and Areas of Bars and Plates

Size or thickness (inches)		Square and round bars				Plates 1 foot wide	
		Weight (pounds per foot)		Area (square inches)		Weight (pounds per foot)	Area (square inches)
		Square	Round	Square	Round		
1/4		0. 213	0. 167	0. 0625	0. 0491	10. 20	3. 00
3/8		. 478	. 376	. 1406	. 1105	15. 30	4. 50
1/2		. 850	. 668	. 2500	. 1963	20. 40	6. 00
5/8		1. 328	1. 403	. 3906	. 3068	25. 50	7. 50
3/4		1. 913	1. 502	. 5625	. 4418	30. 60	9. 00
7/8		2. 603	2. 044	. 7656	. 6013	35. 70	10. 50
1		3. 400	2. 670	1. 0000	. 7854	40. 80	12. 00
1 1/8		4. 303	3. 380	1. 2656	. 9940	45. 90	13. 50
1 1/4		5. 313	4. 172	1. 5625	1. 2272	51. 00	15. 00
1 1/2		7. 650	6. 008	2. 2500	1. 7671	61. 20	18. 00
2		13. 600	10. 681	4. 00	3. 1416	81. 60	24. 00
2 1/2		21. 250	16. 690	6. 25	4. 9087	102. 00	30. 00
3	"	30. 600	24. 033	9. 00	7. 0686	122. 40	36. 00
3 1/2		41. 65	32. 71	12. 25	9. 621	142. 80	42. 00
4		54. 40	42. 73	16. 00	12. 566	163. 20	48. 00
Size or thickness							
(millimeters)	(inches)						
5	0. 20	. 136	. 103	. 04	. 03	7. 990	2. 35
6	. 24	. 204	. 149	. 06	. 05	9. 622	2. 83
7	. 28	. 272	. 203	. 08	. 06	11. 254	3. 31
8	. 32	. 340	. 265	. 10	. 08	12. 852	3. 78
10	. 39	. 544	. 415	. 16	. 12	16. 082	4. 73
12	. 47	. 748	. 597	. 22	. 17	19. 244	5. 66
14	. 55	1. 020	. 813	. 30	. 24	22. 474	6. 61
16	. 63	1. 258	1. 062	. 37	. 31	25. 704	7. 56
18	. 71	1. 700	1. 344	. 50	. 40	28. 934	8. 51
20	. 79	2. 108	1. 660	. 62	. 49	32. 096	9. 44
22	. 87	2. 550	2. 003	. 75	. 59	35. 326	10. 39
24	. 94	3. 026	2. 386	. 89	. 69	38. 556	11. 34
26	1. 02	3. 570	2. 802	1. 05	. 82	42. 602	12. 53
28	1. 10	4. 148	3. 246	1. 22	. 95	44. 948	13. 22
30	1. 18	4. 760	3. 730	1. 40	1. 09	48. 178	14. 17
32	1. 26	5. 406	4. 240	1. 59	1. 25	51. 408	15. 12
34	1. 34	6. 086	4. 791	1. 79	1. 41	54. 638	16. 07
36	1. 42	6. 834	5. 369	2. 01	1. 58	57. 800	17. 00
38	1. 50	7. 616	5. 981	2. 24	1. 77	61. 030	17. 95
40	1. 57	8. 432	6. 633	2. 48	1. 94	64. 260	18. 90
45	1. 77	10. 676	8. 400	3. 14	2. 46	72. 284	21. 26
50	1. 97	13. 192	10. 349	3. 88	3. 05	80. 342	23. 63

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151. Dimensions and Properties of U.S. Sections

Tables 151 to 154 inclusive are reprinted from "Steel Construction" by permission of the American Institute of Steel Construction (copyright 1947). The WF and angle tables are abridged listings.

a. WF Shapes.

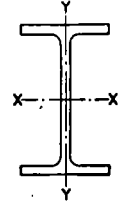
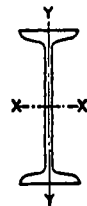


Table 151. WF Shapes

Nominal size	Weight per foot	Area	Depth	Flange		Web thick- ness	Axis X-X			Axis Y-Y			Gage
				Width	Thickness		I	S	r	I	S	r	
In.	Lb	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
36 x 16½	230	67.73	35.88	16.475	1.260	.765	14988.4	835.5	14.88	870.9	105.7	3.59	5½
36 x 12	150	44.16	35.84	11.972	.940	.625	9012.1	502.9	14.29	250.4	41.8	2.38	5½
33 x 11½	130	38.26	33.10	11.510	.855	.580	6699.0	404.8	13.23	201.4	35.0	2.29	5½
30 x 15	172	50.65	29.88	14.985	1.065	.655	7891.5	528.2	12.48	550.1	73.4	3.30	5½
30 x 10½	108	31.77	29.82	10.484	.760	.548	4461.0	299.2	11.85	135.1	25.8	2.06	5½
27 x 10	94	27.65	26.91	9.990	.747	.490	3266.7	242.8	10.87	115.1	23.0	2.04	5½
24 x 12	100	29.43	24.00	12.000	.775	.468	2987.3	248.9	10.08	203.5	33.9	2.63	5½
24 x 9	76	22.37	23.91	8.985	.682	.440	2096.4	175.4	9.68	76.5	17.0	1.85	5½
21 x 8¼	62	18.23	20.99	8.240	.615	.400	1326.8	126.4	8.53	53.1	12.9	1.71	5½
18 x 7½	50	14.71	18.00	7.500	.570	.358	800.6	89.0	7.38	37.2	9.9	1.59	3½
16 x 7	36	10.59	15.85	6.992	.428	.299	446.3	56.3	6.49	22.1	6.3	1.45	3½
14 x 6¾	30	8.81	13.86	6.733	.383	.270	289.6	41.8	5.73	17.5	5.2	1.41	3½
12 x 12	65	19.11	12.12	12.000	.606	.390	533.4	88.0	5.28	174.6	29.1	3.02	5½

12 x 6½----	27	7. 97	11. 95	6. 500	. 400	. 240	204. 1	34. 1	5. 06	16. 6	5. 1	1. 44	3½
10 x 10----	49	14. 40	10. 00	10. 000	. 558	. 340	272. 9	54. 6	4. 35	93. 0	18. 6	2. 54	5½
10 x 5¾----	21	6. 19	9. 90	5. 750	. 340	. 240	106. 3	21. 5	4. 14	9. 7	3. 4	1. 25	2¾
8 x 8-----	31	9. 12	8. 00	8. 000	. 433	. 288	109. 7	27. 4	3. 47	37. 0	9. 2	2. 01	5½
8 x 6½----	24	7. 06	7. 93	6. 500	. 398	. 245	82. 5	20. 8	3. 42	18. 2	5. 6	1. 61	3½
8 x 5¼----	17	5. 00	8. 00	5. 250	. 308	. 230	56. 4	14. 1	3. 36	6. 7	2. 6	1. 16	2¾
6 x 6-----	25	7. 37	63. 7	8. 080	. 456	. 320	53. 5	16. 8	2. 69	17. 1	5. 6	1. 52	3½
4 x 4-----	13	3. 82	4. 16	4. 060	. 345	. 280	11. 3	5. 45	1. 72	3. 76	1. 85	. 99	2¾

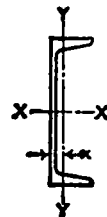


b. American Standard Beams.

Table 152. American Standard Beams

Nominal size	Weight per foot	Area	Depth	Flange		Web thick- ness	Axis X-X			Axis Y-Y		
				Width	Thickness		I	S	r	I	S	r
In.	Lb.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
24 x 7 $\frac{7}{8}$ -----	120. 0	35. 13	24. 00	8. 048	1. 102	0. 798	3010. 8	250. 9	9. 26	84. 9	21. 1	1. 56
	105. 9	30. 98	24. 00	7. 875	1. 102	. 625	2811. 5	234. 3	9. 53	78. 9	20. 0	1. 60
24 x 7-----	100. 0	29. 25	24. 00	7. 247	. 871	. 747	2371. 8	197. 6	9. 05	48. 4	13. 4	1. 29
	90. 0	26. 30	24. 00	7. 124	. 871	. 624	2230. 1	185. 8	9. 21	45. 5	12. 8	1. 32
	79. 9	23. 33	24. 00	7. 000	. 871	. 500	2087. 2	173. 9	9. 46	42. 9	12. 2	1. 36
20 x 7-----	95. 0	27. 74	20. 00	7. 200	. 916	. 800	1599. 7	160. 0	7. 59	50. 5	14. 0	1. 35
	85. 0	24. 80	20. 00	7. 053	. 916	. 653	1501. 7	150. 2	7. 78	47. 0	13. 3	1. 38
20 x 6 $\frac{1}{4}$ -----	75. 0	21. 90	20. 00	6. 391	. 789	. 641	1263. 5	126. 3	7. 60	30. 1	9. 4	1. 17
	65. 4	19. 08	20. 00	6. 250	. 789	. 500	1169. 5	116. 9	7. 83	27. 9	8. 9	1. 21
18 x 6-----	70. 0	20. 46	18. 00	6. 251	. 691	. 711	917. 5	101. 9	6. 70	24. 5	7. 8	1. 09
	54. 7	15. 94	18. 00	6. 000	. 691	. 460	795. 5	88. 4	7. 07	21. 2	7. 1	1. 15
15 x 5 $\frac{1}{2}$ -----	50. 0	14. 59	15. 00	5. 640	. 622	. 550	481. 1	64. 2	5. 74	16. 0	5. 7	1. 05
	42. 9	12. 49	15. 00	5. 500	. 622	. 410	441. 8	58. 9	5. 95	14. 6	5. 3	1. 08

12 x 5¼-----	50.0	14.57	12.00	5.477	.659	.687	301.6	50.3	4.55	16.0	5.8	1.05
	40.8	11.84	12.00	5.250	.659	.460	268.9	44.8	4.77	13.8	5.3	1.08
12 x 5-----	35.0	10.20	12.00	5.078	.544	.428	227.0	37.8	4.72	10.0	3.9	.99
	31.8	9.26	12.00	5.000	.544	.350	215.8	36.0	4.83	9.5	3.8	1.01
10 x 4½-----	35.0	10.22	10.00	4.944	.491	.594	145.8	29.2	3.78	8.5	3.4	.91
	25.4	7.38	10.00	4.660	.491	.310	122.1	24.4	4.07	6.9	3.0	.97
8 x 4-----	23.0	6.71	8.00	4.171	.425	.441	64.2	16.0	3.09	4.4	2.1	.81
	18.4	5.34	8.00	4.000	.425	.270	56.9	14.2	3.26	3.8	1.9	.84
7 x 3¾-----	20.0	5.83	7.00	3.860	.392	.450	41.9	12.0	2.68	3.1	1.6	.74
	15.3	4.43	7.00	3.660	.392	.250	36.2	10.4	2.86	2.7	1.5	.78
6 x 3¾-----	17.25	5.02	6.00	3.565	.359	.465	26.0	8.7	2.28	2.3	1.3	.68
	12.5	3.61	6.00	3.330	.359	.230	21.8	7.3	2.46	1.8	1.1	.72
5 x 3-----	14.75	4.29	5.00	3.284	.326	.494	15.0	6.0	1.87	1.7	1.0	.63
	10.0	2.87	5.00	3.000	.326	.210	12.1	4.8	2.05	1.2	.82	.65
4 x 2½-----	9.5	2.76	4.00	2.796	.293	.326	6.7	3.3	1.56	.91	.65	.58
	7.7	2.21	4.00	2.660	.293	.190	6.0	3.0	1.64	.77	.58	.59
3 x 2¾-----	7.5	2.17	3.00	2.509	.260	.349	2.9	1.9	1.15	.59	.47	.52
	5.7	1.64	3.00	2.330	.260	.170	2.5	1.7	1.23	.46	.40	.53



c. American Standard Channels.

Table 153. American Standard Channels

Nominal size	Weight per foot	Area	Depth	Flange		Web Thick- ness	Axis X-X			Axis Y-Y			
				Width	Average thickness		I	S	r	I	S	r	x
In.	Lb.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
18 x 4 ¹ -----	58.0	16.98	18.00	4.200	0.625	0.700	670.7	74.5	6.29	18.5	5.6	1.04	0.88
	51.9	15.18	18.00	4.100	.625	.600	622.1	69.1	6.40	17.1	5.3	1.06	.87
	45.8	13.38	18.00	4.000	.625	.500	573.5	63.7	6.55	15.8	5.1	1.09	.89
	42.7	12.48	18.00	3.950	.625	.450	549.2	61.0	6.64	15.0	4.9	1.10	.90
15 x 3 ⁸ -----	50.0	14.64	15.00	3.716	.650	.716	401.4	53.6	5.24	11.2	3.8	.87	.80
	40.0	11.70	15.00	3.520	.650	.520	346.3	46.2	5.44	9.3	3.4	.89	.78
	33.9	9.90	15.00	3.400	.650	.400	312.6	41.7	5.62	8.2	3.2	.91	.79
12 x 3-----	30.0	8.79	12.00	3.170	.501	.510	161.2	26.9	4.28	5.2	2.1	.77	.68
	25.0	7.32	12.00	3.047	.501	.387	143.5	23.9	4.43	4.5	1.9	.79	.68
	20.7	6.03	12.00	2.940	.501	.280	128.1	21.4	4.61	3.9	1.7	.81	.70

10 x 2%-----	30. 0	8. 80	10. 00	3. 033	. 436	. 673	103. 0	20. 6	3. 42	4. 0	1. 7	. 67	. 65
	25. 0	7. 33	10. 00	2. 886	. 436	. 526	90. 7	18. 1	3. 52	3. 4	1. 5	. 68	. 62
	20. 0	5. 86	10. 00	2. 739	. 436	. 379	78. 5	15. 7	3. 66	2. 8	1. 3	. 70	. 61
	15. 3	4. 47	10. 00	2. 600	. 436	. 240	66. 9	13. 4	3. 87	2. 3	1. 2	. 72	. 64
9 x 2½-----	20. 0	5. 86	9. 00	2. 648	. 413	. 448	60. 6	13. 5	3. 22	2. 4	1. 2	. 65	. 59
	15. 0	4. 39	9. 00	2. 485	. 413	. 285	50. 7	11. 3	3. 40	1. 9	1. 0	. 67	. 59
	13. 4	3. 89	9. 00	2. 430	. 413	. 230	47. 3	10. 5	3. 49	1. 8	. 97	. 67	. 61
8 x 2¼-----	18. 75	5. 49	8. 00	2. 527	. 390	. 487	43. 7	10. 9	2. 82	2. 0	1. 0	. 60	. 57
	13. 75	4. 02	8. 00	2. 343	. 390	. 303	35. 8	9. 0	2. 99	1. 5	. 86	. 62	. 56
	11. 5	3. 36	8. 00	2. 260	. 390	. 220	32. 3	8. 1	3. 10	1. 3	. 79	. 63	. 58
7 x 2⅝-----	14. 75	4. 32	7. 00	2. 299	. 366	. 419	27. 1	7. 7	2. 51	1. 4	. 79	. 57	. 53
	12. 25	3. 58	7. 00	2. 194	. 366	. 314	24. 1	6. 9	2. 59	1. 2	. 71	. 58	. 53
	9. 8	2. 85	7. 00	2. 090	. 366	. 210	21. 1	6. 0	2. 72	. 98	. 63	. 59	. 55
6 x 2-----	13. 0	3. 81	6. 00	2. 157	. 343	. 437	17. 3	5. 8	2. 13	1. 1	. 65	. 53	. 52
	10. 5	3. 07	6. 00	2. 034	. 343	. 314	15. 1	5. 0	2. 22	. 87	. 57	. 53	. 50
	8. 2	2. 39	6. 00	1. 920	. 343	. 200	13. 0	4. 3	2. 34	. 70	. 50	. 54	. 52
5 x 1¾-----	9. 0	2. 63	5. 00	1. 885	. 320	. 325	8. 8	3. 5	1. 83	. 64	. 45	. 49	. 48
	6. 7	1. 95	5. 00	1. 750	. 320	. 190	7. 4	3. 0	1. 95	. 48	. 38	. 50	. 49
4 x 1⅝-----	7. 25	2. 12	4. 00	1. 720	. 296	. 320	4. 5	2. 3	1. 47	. 44	. 35	. 46	. 46
	5. 4	1. 56	4. 00	1. 580	. 296	. 180	3. 8	1. 9	1. 56	. 32	. 29	. 45	. 46
3 x 1½-----	6. 0	1. 75	3. 00	1. 596	. 273	. 356	2. 1	1. 4	1. 08	. 31	. 27	. 42	. 46
	5. 0	1. 46	3. 00	1. 498	. 273	. 258	1. 8	1. 2	1. 12	. 25	. 24	. 41	. 44
	4. 1	1. 19	3. 00	1. 410	. 273	. 170	1. 6	1. 1	1. 17	. 20	. 21	. 41	. 44

¹ Car and Shipbuilding Channel, not an American Standard.

d. Selected Angles.

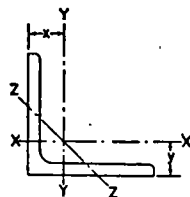
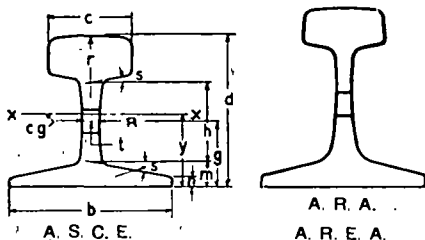


Table 154. Selected Angles

Size	Thick- ness	Weight per ft.-lb.	Area (sq. in.)	Axis X-X			Axis Y-Y			Axis Z-Z
				I	S	r	l	S	r	r
				<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
8 x 8----	1	51. 0	15. 00	89. 0	15. 8	2. 44	-----	-----	-----	1. 56
6 x 6----	$\frac{7}{8}$	33. 1	9. 73	31. 9	7. 6	1. 81	-----	-----	-----	1. 17
5 x 5----	$\frac{3}{4}$	23. 6	6. 94	15. 7	4. 5	1. 51	<i>S</i>	-----	<i>A</i>	. 97
4 x 4----	$\frac{1}{2}$	12. 8	3. 75	5. 6	2. 0	1. 22	<i>A</i>	<i>A</i>	<i>X</i>	. 78
	$\frac{3}{8}$	9. 8	2. 86	4. 4	1. 5	1. 23	<i>M</i>	<i>S</i>	<i>I</i>	. 79
	$\frac{5}{16}$	8. 2	2. 40	3. 7	1. 3	1. 24	<i>E</i>	-----	<i>S</i>	. 79
3½ x 3½--	$\frac{5}{16}$	7. 2	2. 09	2. 5	. 98	1. 08	-----	-----	-----	. 69
3 x 3----	$\frac{3}{16}$	6. 1	1. 78	1. 5	. 71	. 92	-----	-----	<i>X-X</i>	. 59
2 x 2----	$\frac{1}{4}$	3. 19	. 94	. 35	. 25	. 61	-----	-----	-----	. 39
8 x 6----	$\frac{3}{4}$	33. 8	9. 94	63. 4	11. 7	2. 53	30. 7	6. 9	1. 76	1. 29
6 x 4----	$\frac{1}{2}$	16. 2	4. 75	17. 4	4. 3	1. 91	6. 3	2. 1	1. 15	. 87
	$\frac{3}{8}$	12. 3	3. 61	13. 5	3. 3	1. 93	4. 9	1. 6	1. 17	. 88
5 x 3½----	$\frac{3}{8}$	10. 4	3. 05	7. 8	2. 3	1. 60	3. 2	1. 2	1. 02	. 76
	$\frac{3}{16}$	8. 7	2. 56	6. 6	1. 9	1. 61	2. 7	1. 0	1. 03	. 76
5 x 3----	$\frac{3}{8}$	9. 8	2. 86	7. 4	2. 2	1. 61	2. 0	. 89	. 84	. 65
	$\frac{5}{16}$	8. 2	2. 40	6. 3	1. 9	1. 61	1. 8	. 75	. 85	. 66
4 x 3----	$\frac{3}{8}$	8. 5	2. 48	4. 0	1. 5	1. 26	1. 9	. 87	. 88	. 64
	$\frac{5}{16}$	7. 2	2. 09	3. 4	1. 2	1. 27	1. 7	. 73	. 89	. 65
3½ x 3----	$\frac{5}{16}$	6. 6	1. 93	2. 3	. 95	1. 10	1. 6	. 72	. 90	. 63

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e. *Steel Rails.* Under the policies of the Department of Defense, U.S. made steel rails approved for use by the Corps of Engineers are confined to the following types: For ordinary use, 85-pound A.S.C.E. minimum; as an alternative, if economically justified, 90-pound A.R.A.-A.; for heavier duty (on main lines and access or other tracks where the movement may be classified as "heavy" or where the desired speed exceeds 40 miles per hour), 115-pound A.R.E.A. sections. All such rails must conform to military specifications. Figure 75 shows cross sections of A.S.C.E. rails and of A.R.A. and A.R.E.A. rails and their characteristics.



Type	Weight per Yard, in Pounds	DIMENSIONS IN INCHES														PROPERTIES				
		Depth	BASE				HEAD			WEB			Gage	Gross Area	On Horiz. Axis					
			Width	Thickness	Slope in (Degrs)	Width c		Radius	Min. Thick.	h	Radius	I			S	y				
						Top	Bot.													
																	d	b	m	n	a	Top	Bot.	r	t	h	R	g	In.^{2}	In.^{4}	In.^{3}	In.
A. S. C. E.	85	5 3/16	5 3/16	57/64	19/64	13	2 9/16	2 9/16	12	9/16	2 3/4	12	2 17/64	8.33	30.1	2.47	11.1			
A. S. C. E.	90	5 5/8	5 5/8	1	23/64	14	2 13/32	2 9/16	14	9/16	3 5/32	14	2 37/64	8.82	38.7	12.6	2.54			
A. S. C. E.	115	6 5/8	6 1/52	1 1/8	7/16	14	2 21/32	2 21/32	10	5/8	3 13/16	com.	2 7/8	11.25	65.6	18.0	2.98			

Figure 75. Dimensions and properties of currently produced steel rails.

*f. Steel Pipe.*Table 155. *Steel Pipe*

Dimensions							Couplings			Properties		
Nominal diameter (inches)	Outside diameter (inches)	Inside diameter (inches)	Thick- ness (inches)	Weight per foot-pound		Threads per inch	Outside diameter (inches)	Length (inches)	Weight (pounds)	I (inches)	A (inches)	r (inches)
				Plain ends	Thread & cplg.							
STANDARD												
1/8-----	0. 405	0. 269	0. 068	0. 24	0. 25	27	0. 562	7/8	0. 03	0. 001	0. 072	0. 12
1/4-----	. 540	. 364	. 088	. 42	. 43	18	. 685	1	. 04	. 003	. 125	. 16
3/8-----	. 675	. 493	. 091	. 57	. 57	18	. 848	1 1/8	. 07	. 007	. 167	. 21
1/2-----	. 840	. 622	. 109	. 85	. 85	14	1. 024	1 1/2	. 12	. 017	. 250	. 26
3/4-----	1. 050	. 824	. 113	1. 13	1. 13	14	1. 281	1 3/4	. 21	. 037	. 333	. 33
1-----	1. 315	1. 049	. 133	1. 68	1. 68	11 1/2	1. 576	1 3/4	. 35	. 087	. 494	. 42
1 1/4-----	1. 660	1. 380	. 140	2. 27	2. 28	11 1/2	1. 950	2 1/8	. 55	. 195	. 669	. 54
1 1/2-----	1. 900	1. 610	. 145	2. 72	2. 73	11 1/2	2. 218	2 3/8	. 76	. 310	. 799	. 62
2-----	2. 375	2. 067	. 154	3. 65	3. 68	11 1/2	2. 760	2 3/4	1. 23	. 666	1. 075	. 79
2 1/2-----	2. 875	2. 469	. 203	5. 79	5. 82	8	3. 276	2 7/8	1. 76	1. 530	1. 704	. 95
3-----	3. 500	3. 068	. 216	7. 58	7. 62	8	3. 948	3 1/8	2. 55	3. 017	2. 228	1. 16
3 1/2-----	4. 000	3. 548	. 226	9. 11	9. 20	8	4. 591	3 3/8	4. 33	4. 788	2. 680	1. 34
4-----	4. 500	4. 026	. 237	10. 79	10. 89	8	5. 091	3 3/8	5. 41	7. 233	3. 174	1. 51
5-----	5. 563	5. 047	. 258	14. 62	14. 81	8	6. 296	4 1/8	9. 16	15. 16	4. 300	1. 88
6-----	6. 625	6. 065	. 280	18. 97	19. 19	8	7. 358	4 1/8	10. 82	28. 14	5. 581	2. 25
8-----	8. 625	8. 071	. 277	24. 70	25. 00	8	9. 420	4 3/8	15. 84	63. 35	7. 265	2. 95
8-----	8. 625	7. 981	. 322	28. 55	28. 81	8	9. 420	4 3/8	15. 84	72. 49	8. 399	2. 94
10-----	10. 750	10. 192	. 279	31. 20	32. 00	8	11. 721	6 1/8	33. 92	125. 9	9. 178	3. 70
10-----	10. 750	10. 136	. 307	34. 24	35. 00	8	11. 721	6 1/8	33. 92	137. 4	10. 07	3. 69
10-----	10. 750	10. 020	. 365	40. 48	41. 13	8	11. 721	6 1/8	33. 92	160. 7	11. 91	3. 67
12-----	12. 750	12. 090	. 330	43. 77	45. 00	8	13. 958	6 3/8	48. 27	248. 5	12. 88	4. 39
12-----	12. 750	12. 000	. 375	49. 56	50. 71	8	13. 958	6 3/8	48. 27	279. 3	14. 58	4. 38

EXTRA STRONG

1/8-----	0. 405	0. 215	0. 095	0. 31	0. 32	27	0. 582	1 1/8	0. 05	0. 001	0. 093	0. 11
1/4-----	. 540	. 302	. 119	. 54	. 54	18	. 724	1 3/8	. 07	. 004	. 157	. 15
3/8-----	. 675	. 423	. 126	. 74	. 75	18	. 898	1 5/8	. 13	. 009	. 217	. 20
1/2-----	. 840	. 546	. 147	1. 09	1. 10	14	1. 085	1 7/8	. 22	. 020	. 320	. 25
3/4-----	1. 050	. 742	. 154	1. 47	1. 49	14	1. 316	2 1/8	. 33	. 045	. 433	. 32
1-----	1. 315	. 957	. 179	2. 17	2. 20	11 1/2	1. 575	2 3/8	. 47	. 106	. 639	. 41
1 1/4-----	1. 660	1. 278	. 191	3. 00	3. 05	11 1/2	2. 054	2 5/8	1. 04	. 242	. 881	. 52
1 1/2-----	1. 900	1. 500	. 200	3. 63	3. 69	11 1/2	2. 294	2 7/8	1. 17	. 391	1. 068	. 61
2-----	2. 375	1. 939	. 218	5. 02	5. 13	11 1/2	2. 870	3 1/8	2. 17	. 868	1. 477	. 77
2 1/2-----	2. 875	2. 323	. 276	7. 66	7. 83	8	3. 389	4 1/8	3. 43	1. 924	2. 254	. 92
3-----	3. 500	2. 900	. 300	10. 25	10. 46	8	4. 014	4 3/8	4. 13	3. 894	3. 016	1. 14
3 1/2-----	4. 000	3. 364	. 318	12. 51	12. 82	8	4. 628	4 5/8	6. 29	6. 280	3. 678	1. 31
4-----	4. 500	3. 826	. 337	14. 98	15. 39	8	5. 233	4 7/8	8. 16	9. 610	4. 407	1. 48
5-----	5. 563	4. 813	. 375	20. 78	21. 42	8	6. 420	5 1/8	12. 87	20. 67	6. 112	1. 84
6-----	6. 625	5. 761	. 432	28. 57	29. 33	8	7. 482	5 3/8	15. 18	40. 49	8. 405	2. 20
8-----	8. 625	7. 625	. 500	43. 39	44. 72	8	9. 596	6 1/8	26. 63	105. 7	12. 76	2. 88
10-----	10. 750	9. 750	. 500	54. 74	56. 94	8	11. 958	6 3/8	44. 16	211. 9	16. 10	3. 53
12-----	12. 750	11. 750	. 500	65. 42	68. 02	8	13. 958	6 5/8	51. 99	361. 5	19. 24	4. 34

Table 155. Steel Pipe—Continued

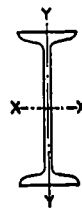
Dimensions							Couplings			Properties		
Nominal diameter (Inches)	Outside diameter (Inches)	Inside diameter (Inches)	Thick- ness (Inches)	Weight per foot-pound		Threads per inch	Outside diameter (Inches)	Length (Inch- es)	Weight (pounds)	I (Inches)	A (Inches)	r (Inches)
				Plain ends	Thread & cplg.							
DOUBLE—EXTRA STRONG												
½-----	0. 840	0. 252	0. 294	1. 71	1. 73	14	1. 085	1⅞	0. 22	0. 024	0. 504	0. 22
¾-----	1. 050	. 434	. 308	2. 44	2. 46	14	1. 316	2⅞	. 33	. 058	. 718	. 28
1-----	1. 315	. 599	. 358	3. 66	3. 68	11½	1. 575	2⅞	. 47	. 140	1. 076	. 36
1¼-----	1. 660	. 896	. 382	5. 21	5. 27	11½	2. 054	2⅞	1. 04	. 341	1. 534	. 47
1½-----	1. 900	1. 100	. 400	6. 41	6. 47	11½	2. 294	2⅞	1. 17	. 568	1. 885	. 55
2-----	2. 375	1. 503	. 436	9. 03	9. 14	11½	2. 870	3⅞	2. 17	1. 311	2. 656	. 70
2½-----	2. 875	1. 771	. 552	13. 70	13. 87	8	3. 389	4⅞	3. 43	2. 871	4. 028	. 84
3-----	3. 500	2. 300	. 600	18. 58	18. 79	8	4. 014	4⅞	4. 13	5. 992	5. 466	1. 05
3½-----	4. 000	2. 728	. 636	22. 85	23. 16	8	4. 628	4⅞	6. 29	9. 848	6. 721	1. 21
4-----	4. 500	3. 152	. 674	27. 54	27. 95	8	5. 233	4⅞	8. 16	15. 28	8. 101	1. 37
5-----	5. 563	4. 063	. 750	38. 55	39. 20	8	6. 420	5⅞	12. 87	33. 64	11. 34	1. 72
6-----	6. 625	4. 897	. 864	53. 16	53. 92	8	7. 482	5⅞	15. 18	66. 33	15. 64	2. 06
8-----	8. 625	6. 875	. 875	72. 42	73. 76	8	9. 596	6⅞	26. 63	162. 0	21. 30	2. 76

LARGE O.D. PIPE

Pipe 14'' and larger is sold by actual O.S. diameter and thickness.

Sizes, 14'', 15'', and 16'' are available regularly in thicknesses varying by $\frac{1}{16}$ '' from $\frac{1}{4}$ '' to 1'', inclusive.

All pipe is furnished random length unless otherwise ordered, viz: 12 to 22 feet with privilege of furnishing 5 percent in 6 to 12 foot lengths. Pipe railing is most economically detailed with slip joints and random lengths between couplings.

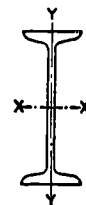


152. Dimensions and Properties of Australian Beams

Table 156. Australian Beams

Ref. No. ASB—	Size	Weight per foot	Area	Depth	Flange		Web thick- ness	Axis X-X			Axis Y-Y		
					Width	Thick- ness		I	S	r	I	S	r
	<i>Inches</i>	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1-----	3 x 1½	4.0	1.18	3	1½	0.249	0.16	1.7	1.1	1.19	0.13	0.17	0.33
2-----	4 x 3	10.0	2.94	4	3	.347	.24	7.8	3.9	1.63	1.32	.88	.67
3-----	4½ x 2	7.0	2.06	4½	2	.322	.19	6.7	3.0	1.80	.38	.38	.43
4-----	6 x 3	12.0	3.53	6	3	.377	.23	21.0	7.0	2.44	1.46	.97	.64
5-----	6 x 5	25.0	7.35	6	5	.561	.33	45.2	15.1	2.48	9.87	3.95	1.16
6-----	7 x 3½	15.0	4.42	7	3½	.398	.25	35.9	10.3	2.85	2.41	1.38	.74
7-----	8 x 4	18.0	5.30	8	4	.398	.28	55.6	13.9	3.24	3.51	1.75	.81
8-----	8 x 6	35.0	10.30	8	6	.648	.35	115.1	28.8	3.34	19.54	6.51	1.38
9-----	9 x 4	21.0	6.18	9	4	.457	.30	81.1	18.0	3.62	4.15	2.07	.82
10-----	10 x 4½	25.0	7.35	10	4½	.505	.30	122.3	24.5	4.08	6.49	2.88	.94
11-----	10 x 6	40.0	11.77	10	6	.709	.36	204.8	41.0	4.17	21.76	7.25	1.36
12-----	10 x 8	55.0	16.18	10	8	.783	.40	288.7	57.7	4.22	54.74	13.69	1.84
13-----	12 x 5	30.0	8.83	12	5	.507	.33	206.9	34.5	4.84	8.77	3.51	1.00
14-----	12 x 8	65.0	19.12	12	8	.904	.43	487.8	81.3	5.05	65.18	16.30	1.85
15-----	13 x 5	35.0	10.30	13	5	.604	.35	283.5	43.6	5.25	10.82	4.33	1.03
16-----	14 x 5½	40.0	11.77	14	5½	.627	.37	377.1	53.9	5.66	14.79	5.38	1.12
17-----	15 x 6	45.0	13.24	15	6	.655	.38	491.9	65.6	6.09	19.87	6.62	1.23
18-----	16 x 6	50.0	14.71	16	6	.726	.40	618.1	77.3	6.48	22.47	7.49	1.24

19_-----	16 x 8	75.0	22.06	16	8	.938	.48	973.9	121.7	6.64	68.30	17.08	1.76
20_-----	18 x 6	55.0	16.18	18	6	.757	.42	841.8	93.5	7.21	23.64	7.88	1.21
21_-----	20 x 6½	65.0	19.12	20	6½	.820	.45	1226.2	122.6	8.01	32.56	10.02	1.31
22_-----	22 x 7	75.0	22.06	22	7	.834	.50	1676.8	152.4	8.72	41.07	11.73	1.36
23_-----	24 x 7½	100.0	29.39	24	7½	1.070	.60	2654.8	221.2	9.50	66.87	17.83	1.51

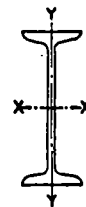


153. Dimensions and Properties of Austrian and Danish Beams

Table 157. Austrian and Danish Beams

Number of profile	Depth in milli- meters	Weight per foot	Area	Depth in inches	Flange		Web thick- ness	Axis X-X			Axis Y-Y		
					Width	Thick- ness		I	S	r	I	S	r
	<i>Milli- meters</i>	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
8.....	80	4. 0	1. 17	3. 15	1. 654	0. 232	0. 154	1. 9	1. 2	1. 28	0. 15	0. 18	0. 36
9.....	90	4. 8	1. 40	3. 54	1. 811	. 248	. 165	2. 8	1. 6	1. 42	. 21	. 23	. 39
10.....	100	5. 6	1. 64	3. 94	1. 969	. 268	. 177	4. 1	2. 1	1. 58	. 29	. 30	. 41
11.....	110	6. 5	1. 91	4. 33	2. 126	. 283	. 189	5. 7	2. 7	1. 73	. 39	. 37	. 45
12.....	120	7. 5	2. 20	4. 72	2. 283	. 303	. 201	7. 9	3. 3	1. 89	. 52	. 45	. 48
13.....	130	8. 5	2. 50	5. 12	2. 441	. 319	. 213	10. 5	4. 1	2. 04	. 66	. 54	. 52
14.....	140	9. 7	2. 84	5. 51	2. 598	. 339	. 224	13. 8	5. 0	2. 24	. 84	. 65	. 55
15.....	150	10. 8	3. 16	5. 90	2. 756	. 354	. 236	17. 7	6. 0	2. 36	1. 05	. 76	. 57
16.....	160	12. 0	3. 53	6. 30	2. 913	. 374	. 248	22. 5	7. 1	2. 52	1. 31	. 90	. 61
17.....	170	13. 3	3. 91	6. 69	3. 071	. 390	. 260	28. 0	8. 3	2. 68	1. 60	1. 04	. 64
18.....	180	14. 7	4. 32	7. 09	3. 228	. 409	. 272	34. 8	9. 8	2. 83	1. 95	1. 21	. 67
19.....	190	16. 1	4. 73	7. 48	3. 386	. 425	. 283	42. 3	11. 3	2. 99	2. 34	1. 39	. 71
20.....	200	17. 7	5. 19	7. 87	3. 543	. 445	. 295	51. 4	13. 0	3. 15	2. 81	1. 59	. 74
21.....	210	19. 2	5. 63	8. 27	3. 700	. 460	. 307	61. 6	14. 9	3. 31	3. 31	1. 79	. 77
22.....	220	20. 9	6. 14	8. 66	3. 858	. 480	. 319	73. 5	17. 0	3. 46	3. 89	2. 01	. 80
23.....	230	22. 5	6. 62	9. 06	4. 016	. 496	. 331	86. 6	19. 2	3. 62	4. 54	2. 26	. 83
24.....	240	24. 3	7. 14	9. 45	4. 173	. 516	. 343	102. 1	21. 6	3. 78	5. 31	2. 54	. 86

25-----	250	26. 2	7. 70	9. 84	4. 331	. 535	. 354	119. 3	24. 2	3. 94	6. 15	2. 83	. 89
26-----	260	28. 2	8. 28	10. 24	4. 449	. 555	. 370	137. 9	27. 0	4. 09	6. 92	3. 11	. 91
27-----	270	30. 2	8. 87	10. 63	4. 567	. 579	. 382	159. 2	30. 0	4. 21	7. 83	3. 43	. 94
28-----	280	32. 3	9. 47	11. 02	4. 685	. 598	. 398	182. 3	33. 1	4. 37	8. 74	3. 73	. 96
29-----	290	34. 2	10. 05	11. 42	4. 803	. 618	. 409	207. 4	36. 4	4. 53	9. 75	4. 06	. 99
30-----	300	36. 4	10. 70	11. 81	4. 921	. 638	. 425	235. 4	39. 8	4. 68	10. 83	4. 41	1. 01
32-----	320	41. 1	12. 05	12. 60	5. 157	. 681	. 453	300. 5	47. 7	5. 00	13. 33	5. 17	1. 05
34-----	340	45. 8	13. 45	13. 39	5. 394	. 720	. 480	377. 1	56. 3	5. 28	16. 19	6. 00	1. 10
36-----	360	51. 2	15. 04	14. 17	5. 630	. 768	. 512	471. 0	66. 5	5. 58	19. 65	6. 96	1. 14
38-----	380	56. 4	16. 57	14. 96	5. 866	. 807	. 539	576. 7	76. 9	5. 89	23. 42	7. 99	1. 19
40-----	400	62. 2	18. 28	15. 75	6. 102	. 850	. 567	701. 6	89. 1	6. 19	27. 82	9. 09	1. 23
42½-----	425	69. 9	20. 45	16. 73	6. 417	. 906	. 602	888. 0	106. 1	6. 58	34. 52	10. 74	1. 30
45-----	450	77. 3	22. 77	17. 72	6. 693	. 957	. 638	1, 101. 4	124. 5	6. 95	41. 43	12. 39	1. 35
47½-----	475	86. 0	25. 25	18. 70	7. 008	1. 008	. 673	1, 356. 7	145. 2	7. 32	50. 15	14. 34	1. 41
50-----	500	94. 8	27. 88	19. 69	7. 283	1. 063	. 708	1, 651. 1	167. 8	7. 69	59. 52	16. 35	1. 46
55-----	550	112. 2	32. 99	21. 65	7. 874	1. 181	. 748	2, 382. 4	220. 3	8. 49	83. 78	21. 30	1. 59

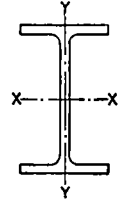


154. Dimensions and Properties of British Standard Beams

Table 158. British Standard Beams

Reference mark	Weight per foot	Area	Depth	Flange		Web thickness	Axis X-X			Axis Y-Y		
				Width	Thickness		I	S	r	I	S	r
	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inch</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
BSB 140-----	95	27. 94	24	7½	1. 011	0. 57	2, 290	190. 8	9. 52	62. 5	16. 7	1. 5
139-----	75	22. 06	22	7	. 834	. 50	1, 505	136. 8	8. 72	41. 1	11. 7	1. 4
138-----	89	26. 19	20	7½	1. 010	. 60	1, 507	150. 7	7. 99	62. 5	16. 7	1. 6
137-----	65	19. 12	20	6½	. 820	. 45	1, 088	108. 8	8. 01	32. 6	10. 0	1. 3
136-----	80	23. 53	18	8	. 950	. 50	1, 167	129. 7	7. 41	69. 4	17. 4	1. 7
135-----	75	22. 09	18	7	. 928	. 55	1, 026	114. 0	7. 22	46. 6	13. 3	1. 5
134-----	55	16. 18	18	6	. 757	. 42	752	83. 6	7. 21	23. 6	7. 9	1. 2
133-----	75	22. 06	16	8	. 938	. 48	878	109. 8	6. 64	68. 3	17. 1	1. 8
132-----	62	18. 21	16	6	. 847	. 55	647	80. 9	6. 31	27. 1	9. 1	1. 2
131-----	50	14. 71	16	6	. 726	. 40	551	68. 9	6. 48	22. 5	7. 5	1. 2
130-----	45	13. 24	15	6	. 655	. 38	439	58. 5	6. 10	19. 9	6. 6	1. 2
129-----	42	12. 36	15	5	. 647	. 42	375	50. 0	5. 89	11. 8	4. 7	1. 0
128-----	70	20. 59	14	8	. 920	. 46	634	90. 6	5. 85	66. 7	16. 7	1. 8
127-----	57	16. 78	14	6	. 873	. 50	473	67. 6	5. 64	27. 9	9. 3	1. 3
126-----	46	13. 59	14	6	. 698	. 40	394	56. 3	5. 71	21. 5	7. 2	1. 3
125-----	35	10. 30	13	5	. 604	. 35	246	37. 8	5. 25	10. 8	4. 3	1. 0
124-----	65	19. 12	12	8	. 904	. 43	437	72. 8	5. 05	65. 2	16. 3	1. 9
123-----	54	15. 89	12	6	. 883	. 50	332	55. 3	4. 86	28. 3	9. 4	1. 3

122-----	44	13.00	12	6	.717	.40	281	46.8	4.94	22.1	7.4	1.3
121-----	32	9.45	12	5	.550	.35	192	32.0	4.84	9.7	3.9	1.0
120-----	55	16.18	10	8	.783	.40	259	51.8	4.22	54.7	13.7	1.8
119-----	40	11.77	10	6	.709	.36	181	40.96	4.17	21.8	7.3	1.4
118-----	30	8.85	10	5	.552	.36	127	25.4	4.06	9.7	3.9	1.1
117-----	25	7.35	10	4½	.505	.30	122	24.5	4.08	6.5	2.9	.9
116-----	50	14.71	9	7	.825	.40	208	46.3	3.76	40.2	11.5	1.7
115-----	21	6.18	9	4	.457	.30	81	18.0	3.62	4.2	2.1	.8
114-----	35	10.30	8	6	.648	.35	115	28.9	3.34	19.5	6.5	1.4
113-----	28	8.28	8	5	.575	.35	90	22.4	3.29	10.2	4.1	1.1
112-----	18	5.30	8	4	.398	.28	56	13.9	3.24	3.5	1.8	.8
111-----	16	4.75	7	4	.387	.25	40	11.3	2.89	3.4	1.7	.8
110-----	25	7.37	6	5	.520	.41	44	14.6	2.44	9.1	3.6	1.1
109-----	20	5.89	6	4½	.431	.37	35	11.6	2.43	5.4	2.4	1.0
108-----	12	3.53	6	3	.377	.23	21	7.0	2.44	1.5	1.0	.6
107-----	20	5.88	5	4½	.513	.29	25	10.0	2.06	6.6	2.9	1.1
106-----	11	3.26	5	3	.376	.22	14	5.5	2.05	1.5	1.0	.7
105-----	6.5	1.91	4¾	1¾	.325	.18	7	2.8	1.88	.3	.3	.4
104-----	10	2.94	4	3	.347	.24	8	3.9	1.63	1.3	.9	.7
103-----	5	1.47	4	1¾	.239	.17	4	1.8	1.58	.2	.2	.4
102-----	8.5	2.52	3	3	.332	.20	4	2.5	1.23	1.3	.8	.7
101-----	4	1.18	3	1½	.249	.16	4	1.1	1.19	.1	.2	.3



155. Dimensions and Properties of German Beams

Table 159. German Wide-Flange Beams

Nominal size (depth in centimeters)	Weight per foot	Area	Depth	Flange		Web thickness	Axis U-U			Axis Y-Y		
				Width	Thickness		I	S	r	I	S	r
	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inch</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
10.....	14	4.05	3.94	3.937	0.393	0.256	10.7	5.4	1.63	4.0	2.0	1.00
12.....	18	5.32	4.72	4.724	.433	.276	20.8	8.8	1.98	7.6	3.2	1.20
14.....	23	6.84	5.51	5.512	.472	.315	36.5	13.2	2.31	13.2	4.8	1.39
16.....	31	9.05	6.30	6.299	.551	.354	63.2	20.1	2.65	23.0	7.3	1.59
18.....	35	10.20	7.09	7.087	.551	.354	92.0	26.0	3.00	32.7	9.2	1.79
20.....	44	12.82	7.87	7.874	.630	.394	142.9	36.3	3.34	51.4	13.1	2.00
22.....	48	14.12	8.66	8.661	.630	.394	193.4	44.7	3.69	68.2	15.7	2.20
24.....	59	17.20	9.44	9.449	.709	.433	280.9	59.4	4.06	99.7	21.1	2.41
26.....	64	18.75	10.24	10.236	.709	.433	361.6	70.8	4.41	126.8	24.9	2.60
28.....	76	22.32	11.02	11.024	.787	.472	497.8	90.3	4.72	175.8	32.0	2.81
30.....	81	23.87	11.81	11.811	.787	.472	618.9	105.0	5.08	216.4	36.7	3.01
32.....	91	26.50	12.60	11.811	.866	.512	774.8	123.3	5.39	238.0	40.4	2.99
34.....	92	26.97	13.39	11.811	.866	.512	887.5	132.4	5.71	238.0	40.4	2.97
36.....	101	29.76	14.17	11.811	.945	.551	1084.0	153.2	6.02	259.7	44.1	2.96
38.....	103	30.07	14.96	11.811	.945	.551	1224.1	163.6	6.38	259.7	44.1	2.94
40.....	110	32.39	15.75	11.811	1.024	.551	1456.9	185.0	6.69	281.3	47.8	2.95
42½.....	112	32.86	16.73	11.811	1.024	.551	1669.3	199.5	7.13	281.3	47.8	2.93
45.....	122	35.96	17.72	11.811	1.102	.591	2023.4	228.2	7.48	303.1	51.4	2.91

47½-----	124	36. 42	18. 70	11. 811	1. 102	. 591	2285. 2	244. 7	7. 91	303. 1	51. 4	2. 88
50-----	134	39. 52	19. 69	11. 811	1. 181	. 630	2719. 6	276. 4	8. 27	325. 0	55. 3	2. 87
55-----	139	40. 76	21. 65	11. 811	1. 181	. 630	3370. 7	311. 2	9. 09	325. 0	55. 3	2. 82
60-----	153	44. 79	23. 61	11. 811	1. 260	. 662	4343. 7	368. 0	9. 84	346. 8	58. 9	2. 78
65-----	157	46. 03	25. 56	11. 811	1. 260	. 662	5208. 6	407. 0	10. 63	346. 8	58. 9	2. 74
70-----	171	50. 22	27. 51	11. 811	1. 339	. 709	6493. 9	471. 1	11. 38	368. 7	62. 5	2. 71
75-----	175	51. 61	29. 47	11. 811	1. 339	. 709	7599. 1	514. 4	12. 13	368. 7	62. 5	2. 67
80-----	180	53. 01	31. 42	11. 811	1. 339	. 709	8802. 7	559. 0	12. 87	368. 7	62. 5	2. 64
85-----	196	57. 66	33. 37	11. 811	1. 417	. 748	10424. 4	637. 1	13. 62	390. 8	66. 1	2. 60
90-----	201	59. 05	35. 33	11. 811	1. 417	. 748	12156. 6	686. 5	14. 33	390. 8	66. 1	2. 57
95-----	206	60. 60	37. 28	11. 811	1. 417	. 748	13786. 3	735. 9	15. 08	390. 8	66. 1	2. 54
100-----	211	62. 00	39. 24	11. 811	1. 417	. 748	15488. 9	787. 2	15. 79	391. 0	66. 1	2. 51

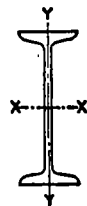
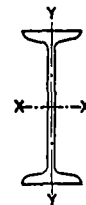


Table 160. German I-Beams

Nominal size (depth in centimeters)	Weight per foot	Area	Depth	Flange		Web thickness	Axis X-X			Axis Y-Y		
				Width	Thickness		I	S	r	I	S	r
	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
8.....	4	1. 17	3. 15	1. 654	0. 232	0. 154	1. 9	1. 3	1. 26	0. 2	0. 2	0. 36
10.....	6	1. 64	3. 94	1. 969	. 268	. 177	4. 1	2. 2	1. 58	. 3	. 3	. 42
12.....	8	2. 20	4. 72	2. 283	. 303	. 201	7. 9	3. 3	1. 89	. 5	. 5	. 48
14.....	10	2. 84	5. 51	2. 598	. 339	. 224	13. 8	5. 0	2. 01	. 8	. 7	. 55
16.....	12	3. 53	6. 30	2. 913	. 374	. 248	22. 5	7. 2	2. 52	1. 3	1. 0	. 61
18.....	15	4. 32	7. 09	3. 228	. 409	. 272	34. 8	9. 8	2. 83	2. 0	1. 3	. 67
20.....	18	5. 19	7. 87	3. 543	. 445	. 295	51. 4	13. 1	3. 15	2. 8	1. 7	. 74
22.....	21	6. 14	8. 66	3. 858	. 480	. 319	73. 5	17. 0	3. 46	3. 9	2. 1	. 80
24.....	24	7. 15	9. 45	4. 173	. 516	. 343	102. 1	21. 6	3. 78	5. 3	2. 5	. 87
26.....	28	8. 28	10. 24	4. 449	. 555	. 370	137. 9	27. 0	4. 09	6. 9	3. 1	. 91
28.....	32	9. 47	11. 02	4. 685	. 598	. 398	182. 3	33. 1	4. 37	8. 7	3. 7	. 96
30.....	36	10. 71	11. 81	4. 921	. 638	. 425	235. 4	39. 8	4. 69	10. 8	4. 4	1. 01
32.....	41	12. 06	12. 60	5. 157	. 681	. 453	300. 6	47. 7	5. 00	13. 3	5. 2	1. 05
34.....	46	13. 45	13. 39	5. 394	. 720	. 480	377. 2	56. 3	5. 31	16. 2	6. 0	1. 10
36.....	51	15. 05	14. 17	5. 630	. 768	. 512	471. 1	66. 5	5. 59	19. 6	7. 0	1. 14
38.....	56	16. 58	14. 96	5. 866	. 807	. 539	576. 8	76. 9	5. 91	23. 4	8. 0	1. 19
40.....	62	18. 29	15. 75	6. 102	. 850	. 567	701. 8	89. 1	6. 18	27. 9	9. 1	1. 23
42½.....	70	20. 46	16. 73	6. 417	. 906	. 602	888. 2	106. 2	6. 57	34. 6	10. 7	1. 30

45-----	77	22. 79	17. 72	6. 693	. 957	. 638	1, 101. 5	124. 5	6. 97	41. 6	12. 4	1. 35
47½-----	86	25. 27	18. 70	7. 008	1. 008	. 673	1, 356. 9	145. 2	7. 32	50. 2	14. 3	1. 42
50-----	95	27. 90	19. 69	7. 283	1. 063	. 709	1, 651. 5	167. 8	7. 72	59. 6	16. 4	1. 46
55-----	112	33. 02	21. 65	7. 874	1. 181	. 748	2, 382. 8	220. 3	8. 50	83. 8	21. 3	1. 58
60-----	134	39. 37	23. 62	8. 465	1. 276	. 850	3, 339. 5	282. 5	9. 21	112. 2	26. 5	1. 69

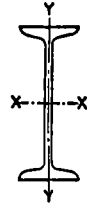


156. Dimensions and Properties of Indian I-Beams

Table 161. Indian I-Beams

Ref No. BSB—	Size	Weight per foot	Area	Depth	Flange		Web thick- ness	Axis X-X			Axis Y-Y		
					Width	Thick- ness		I	S	r	I	S	r
	Inches	Pounds	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
101.....	3x1½	4.0	1.18	3	1½	0.249	0.160	1.7	1.1	1.19	.13	0.17	0.32
103.....	4x1¾	5.0	1.47	4	1¾	.239	.170	3.7	1.8	1.58	.19	.21	.36
105.....	4¾x1¾	6.5	1.91	4¾	1¾	.325	.180	6.7	2.8	1.88	.26	.30	.37
4.....	4 x 3	9.5	2.79	4	3	.336	.220	7.5	3.8	1.64	1.28	.85	.68
104.....	4 x 3	10.0	2.94	4	3	.347	.240	7.8	3.9	1.63	1.33	.88	.67
6.....	5 x 3	11.0	3.24	5	3	.376	.220	13.7	5.5	2.05	1.45	.97	.67
7.....	5 x 4½	18.0	5.29	5	4½	.448	.290	22.7	9.1	2.07	5.66	2.52	1.03
108.....	6 x 3	12.0	3.53	6	3	.377	.230	21.0	7.0	2.44	1.46	.97	.64
110.....	6 x 5	25.0	7.37	6	5	.520	.410	43.7	14.6	2.44	9.10	3.64	1.11
11.....	7 x 4	16.0	4.71	7	4	.387	.250	39.5	11.3	2.89	3.37	1.69	.84
112.....	8 x 4	18.0	5.30	8	4	.398	.280	55.6	13.9	3.24	3.51	1.75	.81
113.....	8 x 5	28.0	8.28	8	5	.575	.350	89.7	22.4	3.29	10.19	4.08	1.11
114.....	8 x 6	35.0	10.30	8	6	.648	.350	115.1	28.8	3.34	19.54	6.51	1.38
117.....	10 x 4½	25.0	7.35	10	4½	.505	.300	122.3	24.5	4.08	6.49	2.88	.94
20.....	12 x 5	32.0	9.41	12	5	.550	.350	192.0	36.8	4.84	9.69	3.88	1.01
21.....	12 x 6	44.0	12.95	12	6	.717	.400	281.0	52.8	4.94	22.12	7.37	1.30
.....	12 x 6	54.0	15.88	12	6	.717	.625						

125-----	13 x 5	35. 0	10. 30	13	5	. 604	. 350	246. 0	43. 6	5. 25	10. 82	4. 33	1. 03
25-----	15 x 5	42. 0	12. 35	15	5	. 647	. 420	375. 0	57. 1	5. 89	11. 81	4. 72	. 98
26-----	15 x 6	59. 0	17. 35	15	6	. 880	. 500	559. 0	83. 9	6. 02	28. 22	9. 41	1. 27
130-----	16 x 6	45. 0	13. 24	16	6	. 665	. 380	439. 0	65. 6	6. 09	19. 87	6. 62	1. 23
131-----	18 x 6	50. 0	14. 71	18	6	. 726	. 400	551. 0	77. 3	6. 48	22. 47	7. 49	1. 24
134-----	18 x 6	55. 0	16. 18	18	6	. 757	. 420	752. 0	93. 5	7. 21	23. 63	7. 88	1. 21
137-----	20 x 6½	65. 0	19. 12	20	6½	. 820	. 450	1088. 0	122. 6	8. 01	32. 56	10. 02	1. 31
139-----	22 x 7	75. 0	22. 06	22	7	. 834	. 500	1505. 0	152. 4	8. 72	41. 07	11. 73	1. 36
NBSB													
6-----	7 x 3½	15. 0	4. 42	7	3½	. 398	. 250	35. 9	10. 3	2. 85	2. 41	1. 38	. 74
8-----	9 x 4	21. 0	6. 18	9	4	. 460	. 300	81. 1	18. 0	3. 62	4. 15	2. 07	. 82
17-----	10 x 5	30. 0	8. 82	10	5	. 552	. 360	127. 0	29. 3	4. 06	9. 73	3. 89	1. 05
10-----	12 x 5	30. 0	8. 82	12	5	. 507	. 330	180. 0	34. 5	4. 84	8. 77	3. 51	1. 00
18-----	24 x 7½	90. 0	26. 47	24	7½	. 984	. 520	-----	-----	-----	-----	-----	-----
-----	24 x 7½	95. 0	27. 91	24	7½	. 984	. 578	-----	-----	-----	-----	-----	-----
-----	24 x 7½	100. 0	29. 40	24	7½	. 984	. 625	-----	-----	-----	-----	-----	-----

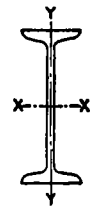


157. Dimensions and Properties of Italian I-Beams

Table 162. Italian I-Beams

Profile	Depth in milli- meters	Weight per foot	Area	Depth in Inches	Flange		Web thick- ness	Axis X-X			Axis Y-Y		
					Width	Thick- ness		I	S	r	I	S	r
	<i>Milli- meters</i>	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
80-----	80	4. 0	1. 18	3. 15	1. 654	0. 232	0. 154	1. 9	1. 2	1. 28	0. 15	0. 18	0. 36
100-----	100	5. 6	1. 64	3. 94	1. 969	. 268	. 177	4. 1	2. 1	1. 58	. 29	. 30	. 42
120-----	120	7. 5	2. 20	4. 72	2. 283	. 303	. 200	7. 9	3. 3	1. 89	. 51	. 45	. 48
140-----	140	9. 7	2. 84	5. 51	2. 598	. 339	. 224	13. 7	5. 0	2. 20	. 84	. 65	. 55
160-----	160	12. 0	3. 54	6. 30	2. 913	. 374	. 248	22. 4	7. 1	2. 52	1. 31	. 90	. 61
180-----	180	14. 7	4. 32	7. 09	3. 228	. 409	. 272	34. 7	9. 8	2. 83	1. 95	1. 21	. 67
200-----	200	17. 7	5. 20	7. 88	3. 543	. 445	. 295	51. 4	13. 1	3. 15	2. 78	1. 58	. 74
220-----	220	21. 4	6. 14	8. 66	3. 858	. 481	. 319	73. 5	17. 0	3. 46	3. 89	2. 02	. 80
240-----	240	24. 3	7. 14	9. 45	4. 173	. 516	. 343	102. 1	21. 6	3. 78	5. 28	2. 53	. 86
250-----	250	26. 1	7. 67	9. 85	4. 331	. 535	. 354	119. 3	22. 8	3. 93	6. 13	2. 83	. 89
260-----	260	28. 2	8. 29	10. 25	4. 449	. 556	. 370	137. 9	27. 0	4. 09	6. 89	3. 11	. 91
280-----	280	32. 2	9. 47	11. 02	4. 685	. 599	. 398	182. 3	33. 1	4. 37	7. 19	3. 72	. 96
300-----	300	36. 4	10. 70	11. 81	4. 921	. 638	. 425	235. 4	39. 8	4. 69	10. 83	4. 39	1. 00
320-----	320	41. 0	12. 05	12. 60	5. 157	. 681	. 453	300. 5	47. 7	5. 00	13. 33	5. 16	1. 05
340-----	340	45. 7	13. 45	13. 39	5. 394	. 721	. 480	377. 1	56. 3	5. 31	16. 19	5. 99	1. 10
360-----	360	51. 2	15. 04	14. 17	5. 630	. 767	. 519	471. 0	66. 5	5. 59	19. 65	6. 95	1. 14

380-----	380	56. 4	16. 57	14. 96	5. 866	. 807	. 539	576. 7	76. 9	5. 91	23. 42	7. 00	1. 19
400-----	400	62. 2	18. 28	15. 75	6. 102	. 851	. 567	701. 6	89. 1	6. 18	27. 82	9. 09	1. 23
425-----	425	69. 9	20. 45	16. 73	6. 417	. 905	. 602	888. 0	106. 1	6. 57	34. 52	10. 74	1. 30
450-----	450	77. 5	22. 77	17. 72	6. 693	. 958	. 638	1, 101. 4	124. 5	6. 97	41. 43	12. 39	1. 35
475-----	475	86. 0	25. 25	18. 70	7. 008	1. 008	. 673	1, 356. 7	144. 9	7. 32	50. 15	14. 28	1. 41
500-----	500	94. 9	27. 88	19. 69	7. 283	1. 063	. 709	1, 651. 1	167. 8	7. 72	59. 52	16. 35	1. 46
550-----	550	112. 5	32. 99	21. 65	7. 874	1. 181	. 748	2, 382. 4	220. 3	8. 50	83. 78	21. 23	1. 58
600-----	600	133. 7	39. 37	23. 62	8. 464	1. 276	. 850	3, 334. 2	282. 2	9. 21	112. 39	26. 54	1. 69

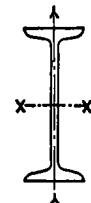


158. Dimensions and Properties of Portuguese I-Beams

Table 163. Portuguese I-Beams

Section	Depth in milli- meters	Weight per foot	Area	Depth in inches	Flange		Web thick- ness	Axis X-X			Axis Y-Y		
					Width	Thick- ness		I	S	r	I	S	r
	<i>Milli- meters</i>	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
10-----	100	13. 8	4. 05	3. 94	3. 937	0. 394	0. 256	10. 7	5. 5	1. 63	4. 0	2. 0	1. 00
12-----	120	18. 1	5. 32	4. 72	4. 724	. 433	. 276	20. 8	8. 8	1. 98	7. 6	3. 2	1. 20
14-----	140	23. 3	6. 84	5. 51	5. 512	. 472	. 315	36. 5	13. 2	2. 31	13. 2	4. 8	1. 39
16-----	160	30. 1	9. 05	6. 30	6. 299	. 551	. 354	63. 2	20. 1	2. 65	23. 0	7. 3	1. 59
18-----	180	34. 7	10. 20	7. 09	7. 086	. 551	. 354	92. 0	26. 0	3. 00	32. 7	9. 2	1. 79
20-----	200	43. 6	12. 82	7. 88	7. 874	. 630	. 394	142. 9	36. 3	3. 34	51. 4	13. 1	2. 00
22-----	220	48. 0	14. 12	8. 66	8. 661	. 630	. 394	193. 4	44. 7	3. 69	68. 2	15. 7	2. 20
24-----	240	58. 7	17. 21	9. 45	9. 449	. 709	. 433	280. 8	59. 4	4. 13	99. 7	21. 1	2. 41
26-----	260	63. 7	18. 76	10. 24	10. 236	. 709	. 433	361. 5	70. 8	4. 41	126. 8	24. 8	2. 60
28-----	280	75. 9	22. 32	11. 02	11. 024	. 788	. 472	497. 7	90. 3	4. 72	175. 8	31. 9	2. 81
30-----	300	81. 3	23. 87	11. 81	11. 811	. 788	. 472	618. 8	105. 0	5. 08	216. 4	36. 6	3. 01
32-----	320	90. 7	26. 51	12. 60	11. 811	. 866	. 512	774. 6	123. 3	5. 39	238. 0	40. 3	2. 99
34-----	340	92. 1	26. 97	13. 39	11. 811	. 866	. 512	887. 3	132. 4	5. 71	238. 0	40. 3	2. 97
36-----	360	100. 8	29. 76	14. 17	11. 811	. 945	. 551	1,083. 8	153. 2	6. 02	259. 7	44. 0	2. 96
38-----	380	102. 8	30. 07	14. 96	11. 811	. 945	. 551	1,223. 8	163. 5	6. 38	259. 7	44. 0	2. 94

40-----	400	110. 2	32. 40	15. 75	11. 811	1. 024	. 551	1, 456. 6	184. 9	6. 69	281. 3	47. 7	2. 95
42½-----	425	111. 5	32. 86	16. 73	11. 811	1. 024	. 551	1, 668. 9	199. 5	7. 13	281. 3	47. 7	2. 93
45-----	450	122. 3	35. 96	17. 71	11. 811	1. 102	. 591	2, 023. 0	228. 2	7. 48	303. 1	51. 3	2. 91
47½-----	475	124. 3	36. 43	18. 70	11. 811	1. 102	. 591	2, 284. 8	244. 7	7. 91	303. 1	51. 3	2. 88
50-----	500	134. 4	39. 53	19. 59	11. 811	1. 181	. 630	2, 719. 1	276. 4	8. 27	325. 0	55. 0	2. 87
55-----	550	139. 1	40. 77	21. 65	11. 811	1. 181	. 630	3, 370. 0	311. 2	9. 09	325. 0	55. 0	2. 82
60-----	600	152. 5	44. 80	23. 62	11. 811	1. 260	. 669	4, 342. 8	368. 0	9. 84	346. 8	58. 7	2. 78
65-----	650	157. 2	46. 04	25. 59	11. 811	1. 260	. 669	5, 207. 5	407. 0	10. 62	346. 8	58. 7	2. 74
70-----	700	170. 6	50. 22	27. 56	11. 811	1. 339	. 709	6, 492. 6	471. 1	11. 37	368. 7	62. 2	2. 71
75-----	750	175. 4	51. 62	29. 53	11. 811	1. 339	. 709	7, 597. 5	514. 4	12. 12	368. 7	62. 2	2. 67
80-----	800	180. 0	53. 01	31. 50	11. 811	1. 339	. 709	8, 800. 9	558. 9	12. 87	368. 7	62. 2	2. 64
85-----	850	196. 2	57. 66	33. 46	11. 811	1. 417	. 748	10, 662. 5	637. 0	13. 62	390. 8	65. 9	2. 60
90-----	900	200. 9	59. 05	35. 43	11. 811	1. 417	. 748	12, 154. 1	686. 5	14. 33	390. 8	65. 9	2. 58
95-----	950	206. 3	60. 61	37. 40	11. 811	1. 417	. 748	13, 763. 5	735. 9	15. 07	390. 8	65. 9	2. 54
100-----	1, 000	211. 0	62. 00	39. 37	11. 811	1. 417	. 748	15, 485. 7	787. 2	15. 78	391. 0	65. 9	2. 51



159. Dimensions and Properties of Russian I-Beams

Table 164. Russian I-Beams

Number of profile	Depth in milli- meters	Weight per foot	Area	Depth in inches	Flange		Web thickness	Axis X-X			Axis Y-Y		
					Width	Thickness		I	S	r	I	S	r
	<i>Milli- meters</i>	<i>Pounds</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
10-----	100	7.5	2.21	3.94	2.677	0.299	0.177	5.9	3.0	1.63	0.79	0.59	0.60
12-----	120	9.4	2.76	4.72	2.913	.331	.197	10.5	4.4	1.95	1.13	.77	.63
14-----	140	11.4	3.33	5.51	3.149	.358	.217	17.1	6.2	2.26	1.55	.98	.68
16-----	160	13.8	4.05	6.30	3.465	.390	.236	27.1	8.6	2.59	2.24	1.29	.74
18-----	180	16.2	4.74	7.09	3.701	.421	.256	39.9	11.3	2.90	2.93	1.59	.79
20a-----	200	18.7	5.50	7.87	3.937	.449	.276	56.9	14.5	3.21	3.79	1.92	.84
20b-----	200	20.9	6.12	7.87	4.016	.449	.354	60.1	15.3	3.14	4.06	2.02	.81
22a-----	220	22.2	6.51	8.66	4.331	.484	.295	81.7	18.9	3.54	5.40	2.50	.91
22b-----	220	24.5	7.19	8.66	4.409	.484	.374	85.8	19.8	3.46	5.74	2.61	.89
24a-----	240	25.1	7.39	9.45	4.567	.512	.315	109.8	23.3	3.85	6.73	2.95	.95
24b-----	240	27.7	8.15	9.45	4.645	.512	.394	115.3	24.4	3.77	7.13	3.08	.94
27a-----	270	28.8	8.46	10.63	4.803	.539	.335	157.3	29.6	4.29	8.29	3.45	.99
27b-----	270	31.7	9.30	10.63	4.881	.539	.413	165.0	31.1	4.21	8.79	3.59	.97
30a-----	300	32.3	9.49	11.81	4.961	.567	.354	215.0	36.4	4.76	9.61	3.87	1.00
30b-----	300	35.4	10.41	11.81	5.039	.567	.433	225.8	38.3	4.65	10.14	4.02	.98
30s-----	300	38.6	11.38	11.81	5.118	.567	.512	236.6	40.1	4.57	10.69	4.18	.97

33a-----	330	35. 9	10. 56	12. 99	5. 118	. 591	. 374	285. 8	44. 0	5. 20	11. 05	4. 31	1. 06
33b-----	330	39. 4	11. 58	12. 99	5. 196	. 591	. 453	300. 3	46. 2	5. 08	11. 63	4. 47	1. 00
33s-----	330	42. 9	12. 60	12. 99	5. 275	. 591	. 531	314. 7	48. 4	5. 00	12. 25	4. 64	. 99
36a-----	360	40. 3	11. 83	14. 17	5. 354	. 622	. 394	378. 6	53. 4	5. 67	13. 26	4. 95	1. 06
36b-----	360	44. 1	12. 94	14. 17	5. 433	. 622	. 472	397. 1	56. 1	5. 55	13. 98	5. 14	1. 04
36s-----	360	47. 8	14. 06	14. 17	5. 511	. 622	. 551	415. 8	58. 7	5. 43	14. 70	5. 33	1. 02
40a-----	400	45. 4	13. 35	15. 75	5. 590	. 650	. 413	521. 7	66. 5	6. 26	15. 85	5. 69	1. 09
40b-----	400	49. 6	14. 59	15. 75	5. 669	. 650	. 492	547. 2	69. 6	6. 14	16. 62	5. 87	1. 07
40s-----	400	53. 8	15. 81	15. 75	5. 748	. 650	. 571	572. 9	72. 6	5. 98	17. 46	6. 08	1. 04
45a-----	450	54. 0	15. 81	17. 71	5. 906	. 709	. 453	774. 4	87. 3	6. 97	20. 53	6. 96	1. 14
45b-----	450	58. 7	17. 21	17. 71	5. 984	. 709	. 531	810. 9	91. 5	6. 85	21. 47	7. 20	1. 12
45s-----	450	63. 5	18. 60	17. 71	6. 062	. 709	. 610	847. 4	95. 8	6. 73	22. 53	7. 44	1. 10
50a-----	500	62. 9	18. 45	19. 69	6. 220	. 787	. 472	1, 116. 2	113. 5	7. 76	26. 90	8. 66	1. 21
50b-----	500	67. 9	20. 00	19. 69	6. 299	. 787	. 551	1, 166. 4	118. 4	7. 64	28. 10	8. 91	1. 19
50s-----	500	73. 2	21. 55	19. 69	6. 378	. 787	. 630	1, 216. 4	126. 9	7. 48	29. 30	9. 21	1. 17
55a-----	550	70. 6	20. 77	21. 65	6. 535	. 827	. 492	1, 510. 1	139. 7	8. 50	32. 91	10. 01	1. 26
55b-----	550	76. 6	22. 48	21. 65	6. 614	. 827	. 571	1, 576. 7	145. 8	8. 35	34. 11	10. 37	1. 24
55s-----	550	82. 7	24. 18	21. 65	6. 692	. 827	. 650	1, 643. 2	151. 9	8. 23	35. 55	10. 68	1. 21
60a-----	600	79. 3	23. 41	23. 62	6. 929	. 866	. 512	2, 014. 3	170. 9	9. 25	40. 83	11. 78	1. 32
60b-----	600	86. 0	25. 27	23. 62	7. 008	. 866	. 591	2, 100. 8	178. 2	9. 13	42. 52	12. 14	1. 30
60s-----	600	92. 1	27. 13	23. 62	7. 086	. 866	. 669	2, 187. 3	185. 5	8. 98	44. 20	12. 51	1. 28



Wide flange	22-----	220	21.4	6.14	8.66	3.858	.481	.319	73.5	17.0	3.46	3.9	2.0	.80
	24-----	240	24.3	7.14	9.45	4.173	.516	.343	101.9	21.6	3.78	5.3	2.5	.86
	25-----	250	26.1	7.67	9.85	4.331	.535	.354	112.4	22.8	3.93	6.1	2.8	.89
	26-----	260	28.2	8.29	10.24	4.449	.556	.370	138.0	27.0	4.09	6.9	3.1	.91
	28-----	280	32.2	9.47	11.02	4.685	.599	.398	182.2	33.1	4.37	7.2	3.7	.96
	30-----	300	36.4	10.71	11.81	4.921	.638	.425	235.4	39.8	4.69	10.8	4.4	1.00
	32-----	320	41.0	12.06	12.60	5.157	.681	.453	300.5	47.7	5.00	13.3	5.2	1.05
Profile normal	-----	340	45.7	13.45	13.39	5.394	.721	.480	383.5	56.3	5.31	16.2	6.0	1.10
	-----	360	51.2	15.05	14.17	5.630	.767	.519	470.9	66.5	5.59	19.6	7.0	1.14
	-----	380	56.4	16.59	14.96	5.866	.807	.539	576.8	76.9	5.91	23.4	8.0	1.19
	-----	400	62.2	18.29	15.75	6.102	.851	.567	701.7	89.1	6.18	27.9	9.1	1.23
	-----	450	77.5	22.79	17.72	6.693	.958	.638	1,101.4	124.5	6.97	41.6	12.4	1.35
	-----	500	94.9	27.90	19.69	7.283	1.063	.709	1,651.1	167.8	7.72	59.6	16.4	1.46
	-----	550	112.5	33.02	21.65	7.874	1.181	.748	2,382.4	220.3	8.50	83.8	21.3	1.58

161. Safe Loads on Angles and Steel Pipes

a. Safe Loads on Angles Used as Beams. Allowable uniform load in kips for angles supported laterally and with longer leg vertical are shown in table 166.

Table 166. Safe Loads on Angles in Kips

Size	Span in feet										
	4	5	6	7	8	9	10	12	14	16	18
8 x 8 x 1	52	42	35	30	26	23	21	17.6	15.0	13.2	11.7
6 x 6 x 7/16	13.7	10.9	9.1	7.8	6.8	6.1	5.5	4.6	3.9		
5 x 5 x 3/8	13.0	10.4	8.7	7.4	6.5	5.8	5.2				
4 x 3 x 1/2	6.3	5.1	4.2	3.6	3.2						
4 x 3 x 3/8	5.0	4.0	3.3	2.9	2.5						
4 x 3 x 5/16	4.0	3.2	2.7	2.3	2.0						
3 1/2 x 3 1/2 x 5/16	3.3	2.6	2.2	1.9	1.6						
3 x 3 x 1/4	1.9	1.5	1.3								
2 1/2 x 2 x 1/4	0.8										
8 x 6 x 3/4	39	31	26	22	19.5	17.3	15.6	13.0	11.1	9.7	
8 x 4 x 1/2	25	20	16.7	14.3	12.5	11.1	10.0	8.3	7.1	6.2	
6 x 4 x 3/8	11.0	8.8	7.3	6.3	5.5	4.9	4.4	3.7			
5 x 3 1/2 x 3/8	7.7	6.1	5.1	4.4	3.8	3.4	3.1				
5 x 3 1/2 x 5/16	6.3	5.1	4.2	3.6	3.2	2.8	2.5				
4 x 3 1/2 x 5/16	4.3	3.5	2.9	2.5	2.2	1.9					
4 x 3 x 1/2	6.3	5.1	4.2	3.6	3.2						
4 x 3 x 3/8	5.0	4.0	3.3	2.9	2.5						
4 x 3 x 5/16	4.0	3.2	2.7	2.3	2.0						
3 1/2 x 3 x 1/4	2.6	2.1	1.7	1.5							

b. Safe Loads on Steel-Pipe Columns. Allowable concentric loads in kips are given in table 167. The loads below the heavy lines are for secondary members with l/r ratios between 120 and 200. For main members of these lengths, use the column formula in paragraph 149a and radii of gyration in paragraph 151.

Table 167. Safe Loads on Pipes

Standard												
Unbraced length (feet)	Nominal diameter—weight per foot											
	12		10			8		6	5	4	3 1/2	3
	49.56	43.77	40.48	34.24	31.20	28.55	24.70	18.97	14.62	10.79	9.11	7.58
6	246	217	200	169	154	140	121	92	70	50	42	33
8	244	216	199	168	153	138	120	90	68	47	38	30
10	243	214	196	166	151	136	118	86	64	44	35	26
12	240	212	194	164	149	133	115	82	61	40	30	21
14	237	210	190	161	147	129	112	79	56	34	25	18
16	234	207	187	158	144	125	109	74	51	30	22	16
18	231	204	182	154	141	121	105	69	45	26	19	13
20	227	200	178	151	137	115	100	63	41	23	17	
22	222	196	172	146	133	109	95	56	37	21	15	

Table 167. Safe Loads on Pipes—Continued

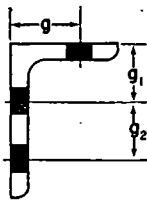
Extra strong								
Unbraced length (feet)	Nominal diameter—weight per foot							
	12	10	8	6	5	4	3½	3
	65.42	54.74	43.39	28.57	20.78	14.98	12.51	10.25
6-----	325	271	213	139	99	70	58	45
8-----	323	268	210	135	96	65	53	40
10-----	320	265	206	131	91	60	47	35
12-----	317	261	201	125	85	54	40	28
14-----	313	257	196	119	79	47	34	24
16-----	309	252	189	112	71	40	30	21
18-----	304	246	192	103	63	36	26	18
20-----	299	239	173	94	56	32	23	-----
22-----	293	232	164	84	51	28	-----	-----
24-----	286	224	155	77	46	25	-----	-----

Double extra strong						
Unbraced length (feet)	Nominal diameter—weight per foot					
	8	6	5	4	3½	3
	72.42	53.16	38.55	27.54	22.85	18.58
6-----	355	257	183	130	103	80
8-----	350	249	176	118	93	70
10-----	343	240	165	108	82	59
12-----	334	228	154	94	68	48
14-----	324	213	140	79	58	40
16-----	312	200	125	70	50	34
18-----	299	182	109	61	43	-----
20-----	284	163	98	54	38	-----
22-----	269	147	88	47	-----	-----
24-----	250	135	80	-----	-----	-----
26-----	230	124	72	-----	-----	-----

162. Riveted Connections

a. Machine fabrication of structural steel for buildings requires a uniform diameter for rivets and field bolts for riveted and bolted structures. It is universal practice to use $\frac{3}{4}$ -inch rivets and bolts in $\frac{1}{16}$ -inch punched holes in such structures. A minimum steel thickness of $\frac{5}{16}$ inch is required to develop bearing value equivalent to the shearing value of a $\frac{3}{4}$ -inch rivet. For $\frac{3}{4}$ -inch rivets the minimum driving clearance for satisfactory shop riveting is $1\frac{1}{4}$ inches from the center of the rivet, so that the narrowest angle leg satisfactory for $\frac{3}{4}$ -inch rivets is 3 inches (usual gage is $1\frac{1}{4}$ inches for 3-inch angles).

The lightest member composed of a pair of angles for a riveted truss is thus two angles 3 by 2½ by ⅝ inches, and the minimum gusset-plate thickness is thus ⅝ inch. The above factors affect the spacing and panel arrangements of riveted trusses. Usual gages for various angles (in inches) are—



Leg-----	8	7	6	5	4	3½	3	2½	2	1¾	1½	1⅜	1¼	1
g-----	4½	4	3½	3	2½	2	1¾	1⅜	1⅛	1	⅞	⅞	¾	⅝
g1-----	3	2½	2¼	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
g2-----	3	3	2½	1¾	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

b. The minimum WF section suitable for use as a column to receive the ends of floorbeams from two directions 90° apart is an 8- by 6½-inch WF, 24 pounds per foot. Seated connections with rivets 3½ inches center to center can be riveted or bolted to flanges and web of this section. The usual rivet gage is 3½ inches in WF beam flanges 6½ to 7½ inches wide, and 5½ inches in flanges 8 inches and wider. The 8- by 8-inch WF, 31 pounds per foot, is therefore the lightest section on which standard connection angles can be riveted or bolted to the flanges.

163. Welded Connections

a. *Types of Welded Joints.* The joints shown in figure 76 are types accepted without qualification under the A.W.S. code and under the A.I.S.C. specifications.

b. *Welding Symbols for Use on Drawings.* The symbols shown in figure 77 are those developed by the American Welding Society for use on drawings specifying arc or gas welding. See also TM 5-704.

c. *Effective Areas of Weld Metal.* The strength of welded connections is based on unit stresses for welds as given in paragraph 149a and on effective areas of weld metal as shown in table 168.

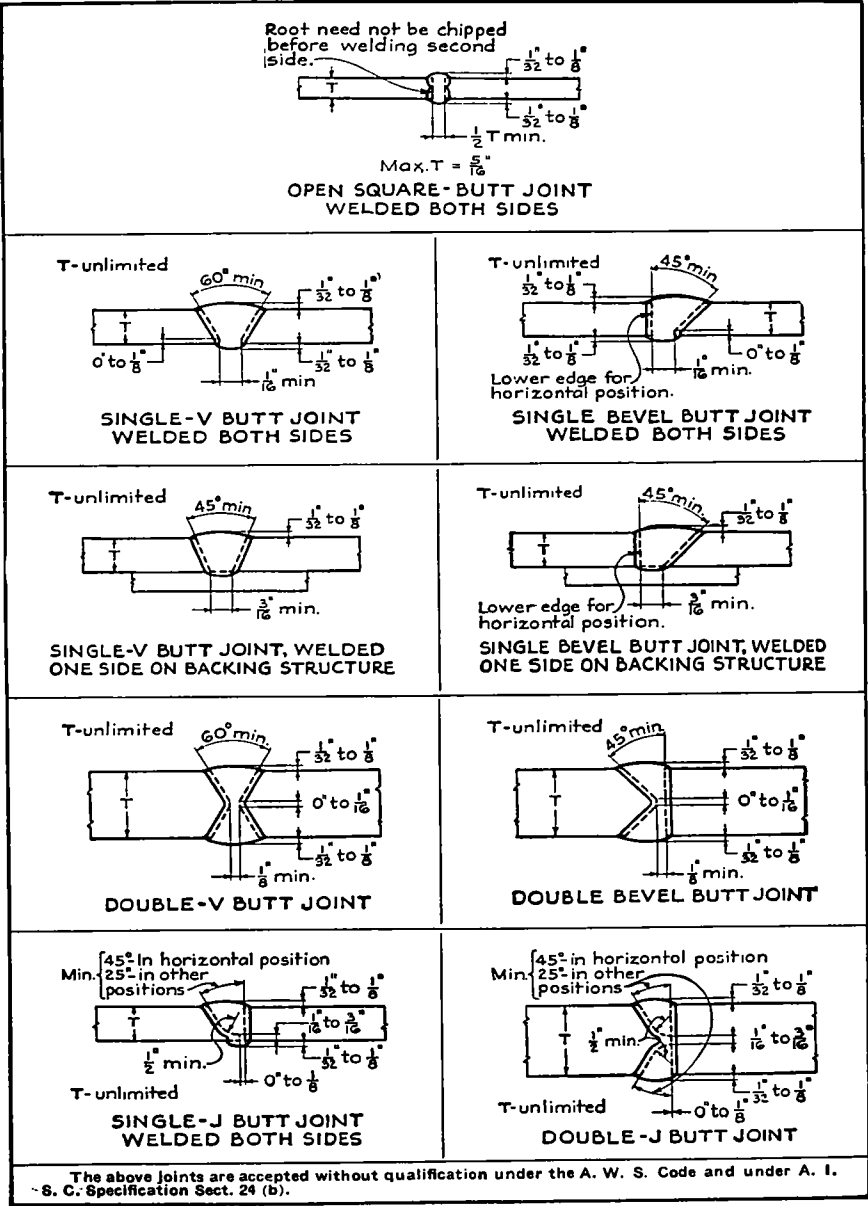
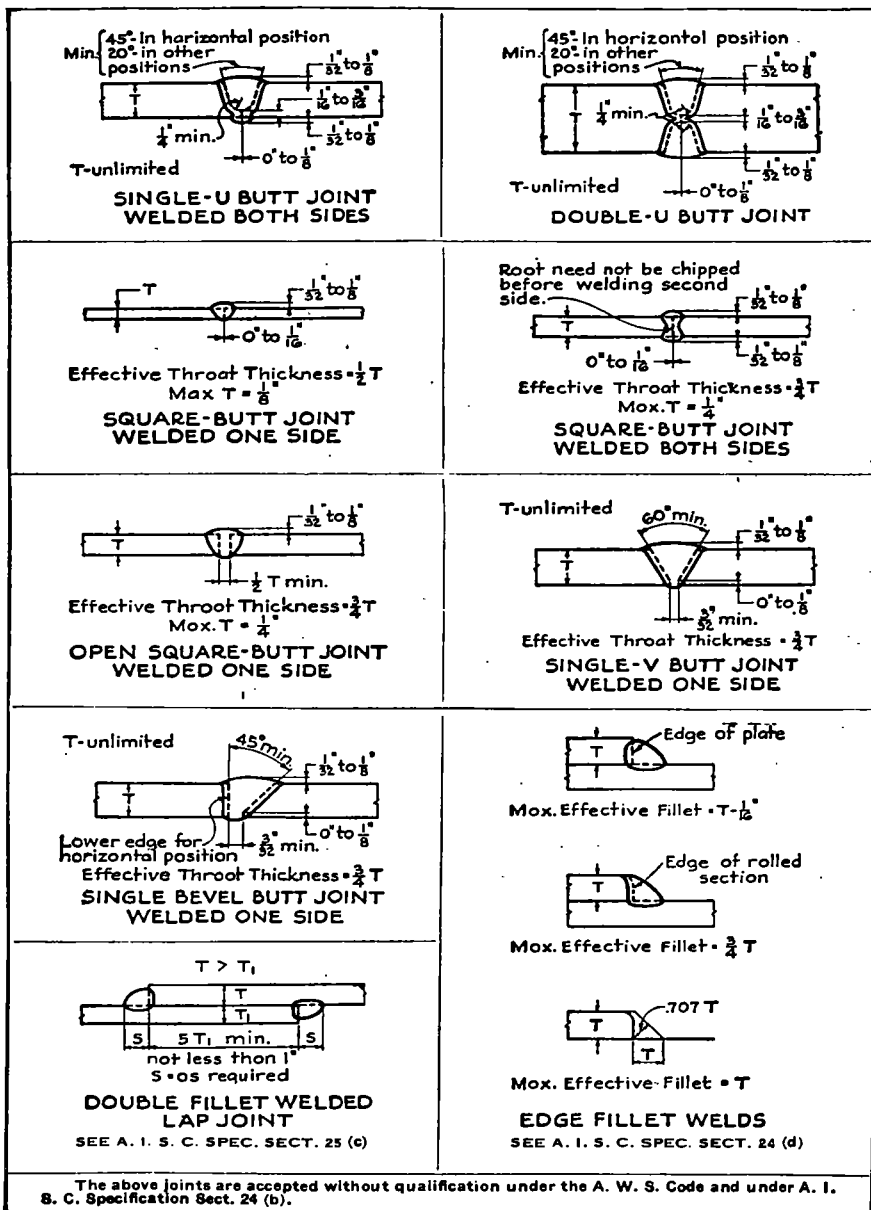


Figure 76. Types of welded joints.



The above joints are accepted without qualification under the A. W. S. Code and under A. I. S. C. Specification Sect. 24 (b).

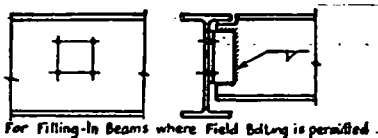
Figure 76—Continued

Table 168. Effective Weld Areas

Type of weld	Effective length	Effective throat thickness
Butt welds, complete penetration.	Width of part joined...	Thickness of thinner part joined.
Butt welds, incomplete penetration.		75% of thickness of thinner part joined.
Fillet welds.....	Over-all length of full-size fillet, including returns.	Shortest distance from root to faee (0.707 times nominal size for an equal-leg 45° weld.)
Plug and slot welds...	Shearing area is nominal area of hole or slot in plane of faying (econtact) surfacee.	
Fillet welds in holes or slots.	Shearing area is effective area of fillet, but not to exceed nominal area of hole or slot.	

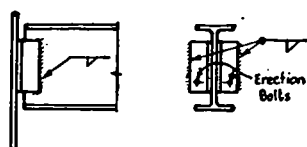
ARC AND GAS WELDING SYMBOLS									
TYPE OF WELD							FIELD WELD	WELD ALL AROUND	FLUSH
BEAD	FILLET	GROOVE				PLUG & SLOT			
		SQUARE	V	BEVEL	U	J			
LOCATION OF WELDS									
ARROW (OR NEAR) SIDE OF JOINT		OTHER (OR FAR) SIDE OF JOINT		BOTH SIDES OF JOINT					
1. THE SIDE OF THE JOINT TO WHICH THE ARROW POINTS IS THE ARROW (OR NEAR) SIDE AND THE OPPOSITE SIDE OF THE JOINT IS THE OTHER (OR FAR) SIDE. 2. ARROW SIDE AND OTHER SIDE WELDS ARE SAME SIZE UNLESS OTHERWISE SHOWN. 3. SYMBOLS APPLY BETWEEN ABRUPT CHANGES IN DIRECTION OF JOINT OR AS DIMENSIONED. (EXCEPT WHERE ALL AROUND SYMBOL IS USED). 4. ALL WELDS ARE CONTINUOUS AND OF USER'S STANDARD PROPORTIONS. UNLESS OTHERWISE SHOWN 5. TAIL OF ARROW USED FOR SPECIFICATION REFERENCE (TAIL MAY BE OMITTED WHEN REFERENCE NOT USED.) E. G. "C. A."—AUTOMATIC SHIELDED CARBON ARC "S. A."—AUTOMATIC SUBMERGED ARC 6. IN JOINTS IN WHICH ONE MEMBER ONLY IS TO BE GROOVED. ARROW POINTS TO THAT MEMBER 7. DIMENSIONS OF WELD SIZES, INCREMENT LENGTHS, AND SPACINGS. IN INCHES.									

Figure 77. Welding symbols

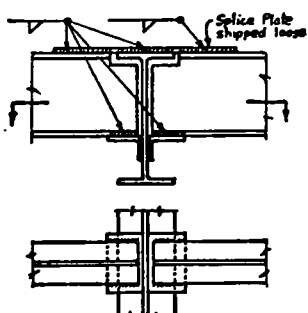


For Filling-In Beams where Field Bolting is permitted.

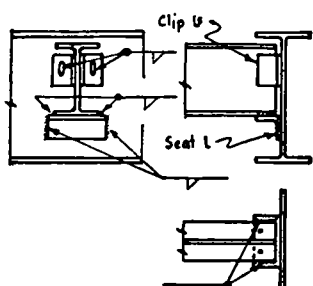
BEAM WELDED - HOLES IN GIRDER



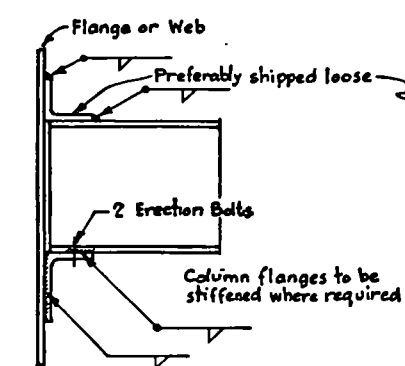
FOR FILLING-IN BEAMS



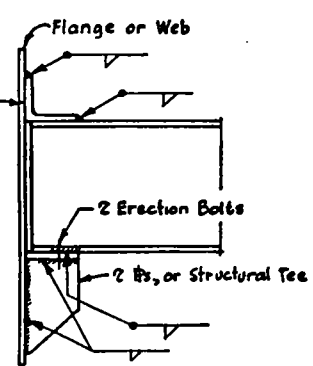
BEAM CONTINUOUS OVER GIRDER



BEAM TO GIRDER



UNSTIFFENED SEAT



STIFFENED SEAT

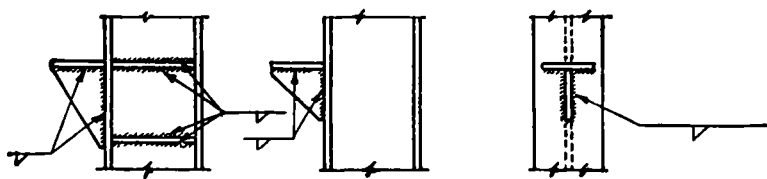


Figure 78. Typical welded-beam connections.

d. Requirement for Unrestrained Beam Connections. The ends of beams and girders must be free to rotate slightly under deflection, by a horizontal displacement of the top flange. Normally this is accomplished by welding only the ends of all connection angles except seat angles, to permit the angles to bend slightly. The amount of horizontal displacement to be provided for is—

$$e = 0.007d \text{ for beams designed for full uniform loads} \\ \text{and for deflections not over } 1/360 \text{ span.}$$

$$\text{or, } e = \frac{fL}{3,625,000} \text{ for beams designed for full uniform loads} \\ \text{producing stress } f \text{ at midspan.}$$

Where e = horizontal displacement of top flange in inches.
 d = depth of beam in inches.
 f = unit stress in pounds per square inch.
 L = span of beam in feet.

e. Details for Welded Connections. Typical details recommended by the American Institute of Steel Construction are shown in figures 78, 79, and 80.

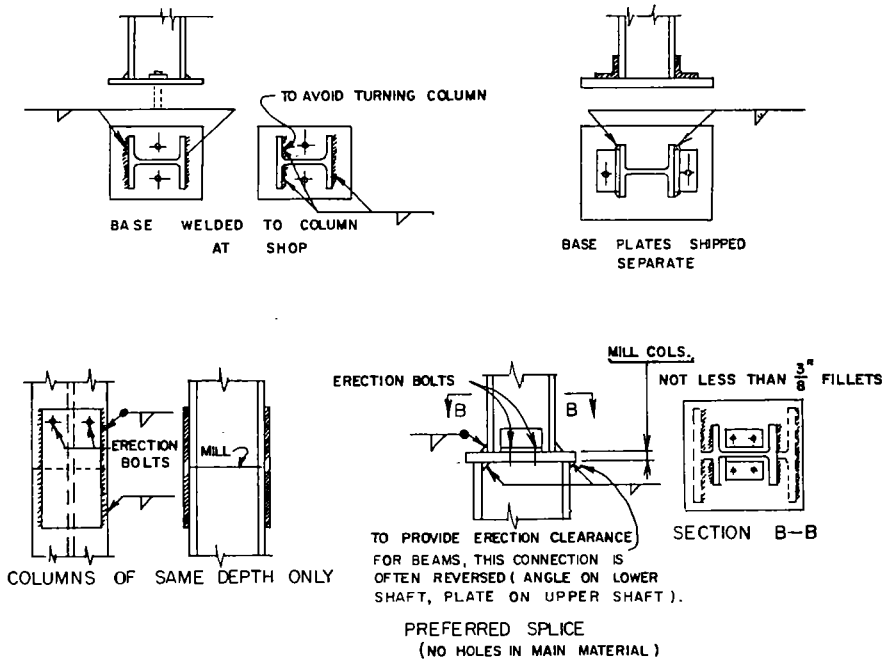


Figure 79. Column bases and splices.

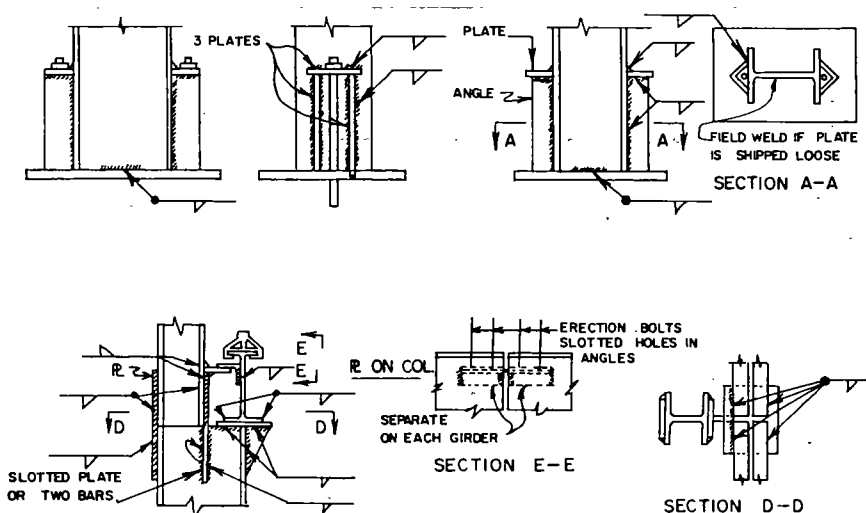


Figure 80. Crane column bases and splices.

Section IV. REINFORCED CONCRETE

164. Working Stresses

a. *Determination of strength of concrete at 28 days.* For plastic mixes, using standard Portland cement and sound, clean, well-graded aggregates, the strength and other desirable properties of concrete under given job conditions are governed by the net quantity of mixing water used per unit of cement. Strength is increased as the quantity of water is reduced. The lowest practicable water-cement ratio is determined by trial mixes. Table 169 gives suggested water-cement ratios for various concrete sections, climatic conditions, and types of structure. The probable 20-day strength is determined from table 170. To allow for field conditions, normally the tabulated strengths are reduced 15 percent pending actual tests.

b. *Slump.* See paragraph 186.

c. *Allowable Unit Stresses in Concrete.* The allowable unit stresses in concrete, in pounds per square inch, shall not exceed the values shown in table 171, where f'_c is the minimum specified compressive strength at 28 days, or at such lesser age as the concrete may be expected to receive its full load. This is based on the following assumptions:

- (1) That the proportions of cement, aggregate, and water have been determined by a method approved by the American Concrete Institute.
- (2) That reinforced concrete members have been designed with reference to allowable stresses, working loads, and the accepted straight-line theory of flexure. In determining

Table 169. Water-Cement Ratios

Type or location of structure	Severe or moderate climate, wide range of temperature, rain, and long freezing spells or frequent freezing and thawing			Mild climate, rain, or semiarid; rarely snow or frost		
	(Gallons/sack ¹)			(Gallons/sack ¹)		
	Thin sections	Moderate sections	Mass sections	Thin sections	Moderate sections	Mass sections
A. At the waterline in hydraulic or waterfront structures or portions of such structures where complete saturation or intermittent saturation is possible, but not where the structure is continuously submerged in water-----	5	5½	6	5	5½	6
B. Portions of hydraulic or waterfront structures some distance from waterline, but subject to frequent wetting by water-----	5½	6	6	5½	6½	7
C. Ordinary exposed structures, buildings, and portions of bridges not coming under above groups-----	6	6½	7	6	7	7½
D. Complete continuous submergence in water-----	6	6½	7	6	6½	7
E. Concrete deposited through water-----	(²)	5½	5½	(²)	5½	5½
F. Pavement slabs directly on ground:						
Wearing slabs-----	5½	(²)	(²)	6	(²)	(²)
Base slabs-----	6½	(²)	(²)	7	(²)	(²)
G. <i>Special case.</i> For concrete not exposed to the weather, such as interiors of buildings and portions of structures entirely below ground, no exposure hazard is involved and the water-cement ratio should be selected on the basis of the strength and workability requirements.						

¹ The figures in this table correspond to U.S. 94-pound bags.

² These sections not practicable for the purpose intended.

Table 170. *Compressive Strengths at 28 Days (for Type I Cement)*

Compressive strength at 28 days (pounds per square inch)	Gallons per bag ¹	Ratio of water to cement		
		Cubic feet per bag ¹	Volume of water, to absolute vol- ume of cement	Weight of water to weight of cement
6,000-----	4	0. 535	1. 12:1	0. 355:1
5,000-----	5	. 668	1. 40:1	. 444:1
4,000-----	6	. 802	1. 68:1	. 533:1
3,300-----	7	. 936	1. 95:1	. 621:1
2,800-----	8	1. 069	2. 23:1	. 710:1

¹ The figures in this table correspond to U.S. 94-pound bags.

the ratio n for design purposes, the modulus of elasticity for the concrete shall be assumed as $1,000 f'_c$ and that for steel as 30,000,000 pounds per square inch; the steel shall be assumed to take all tension stresses in flexural computations.

*d. Allowable Unit Stresses in Reinforcement.*¹ In general, steel for concrete reinforcement should not be stressed in excess of the following limits:

- (1) *Tension.* 20,000 pounds per square inch for rail-steel concrete reinforcing bars, billet-steel concrete reinforcing bars of intermediate and hard grades, axle-steel concrete reinforcing bars of intermediate and hard grades, and cold-drawn steel wire for concrete reinforcement. 18,000 pounds per square inch for billet-steel and axle-steel concrete reinforcing bars of structural grade.
- (2) *Tension in one-way slabs of not more than 12-foot span.* For the main reinforcement, $\frac{3}{8}$ inch or less in diameter, 50 percent of the minimum yield point specified in A.S.T.M. specifications for the particular kind and grade of reinforcement used, but in no case to exceed 30,000 pounds per square inch.
- (3) *Compression, vertical-column reinforcement.* Forty percent of the minimum yield point specified in A.S.T.M. specifications for the particular kind and grade of reinforcement used, but in no case to exceed 30,000 pounds per square inch. For structural-steel sections, 16,000 pounds per square

¹ Data extracted from Journal of the American Concrete Institute, May 1956. Reprinted by permission of A.C.I.

Table 171. Allowable Unit Stresses

Description		For any strength of concrete determined by standard methods $n = \frac{30,000}{f'_c}$	Maximum value (pounds per square inch)	For strength of concrete shown below				
				$f'_c = 2,000$ pounds per square inch; $n = 15$	$f'_c = 2,500$ pounds per square inch; $n = 12$	$f'_c = 3,000$ pounds per square inch; $n = 10$	$f'_c = 3,750$ pounds per square inch; $n = 8$	$f'_c = 5,000$ pounds per square inch; $n = 6$
Flexure: f_c								
Extreme fiber stress in compression	f_c	$0.45 f'_c$	-----	900	1, 125	1, 350	1, 688	2, 250
Extreme fiber stress in tension in plain concrete footings.	f_c	$0.03 f'_c$	-----	60	75	90	113	150
Shear: v (as a measure of diagonal tension):								
Beams with no web reinforcement	v_c	$0.03 f'_c$	-----	60	75	90	90	90
Beams with longitudinal bars and with either stirrups or properly located bent bars.	v	$0.08 f'_c$	-----	240	160	200	240	240
Beams with longitudinal bars and a combination of stirrups and bent bars, the latter bent up suitably to carry at least $0.04 f'_c$	v	$0.12 f'_c$	-----	360	240	300	360	360
Footings ¹	v_c	$0.03 f'_c$	-----	75	60	75	75	75
Bond: u								
Deformed bars: ²								
Top bars ³	u	$0.07 f'_c$	-----	245	140	175	210	245
In 2-way footings (except top bars).	u	$0.08 f'_c$	-----	280	160	200	240	280
All others	u	$0.10 f'_c$	-----	350	200	250	300	350

See footnotes at end of table.

Table 171. Allowable Unit Stresses—Continued

Description		For any strength of concrete determined by standard methods $n = \frac{30,000}{f'_c}$	Maximum value (pounds per square inch)	For strength of concrete shown below				
				$f'_c = 2,000$ pounds per square inch; $n = 15$	$f'_c = 2,500$ pounds per square inch; $n = 12$	$f'_c = 3,000$ pounds per square inch; $n = 10$	$f'_c = 3,750$ pounds per square inch; $n = 8$	$f'_c = 5,000$ pounds per square inch; $n = 6$
Plain bars ⁴ (must be hooked):								
Top bars ³ -----	<i>u</i>	$0.03 f'_c$ -----	105	60	75	90	105	105
In 2-way footings (except top bars).-----	<i>u</i>	$0.036 f'_c$ -----	126	72	90	108	126	126
All others-----	<i>u</i>	$0.045 f'_c$ -----	158	90	113	135	158	158
Bearing: f_c								
On full area-----	f_c	$0.25 f'_c$ -----	-----	500	625	750	938	1, 250
On one-third area or less ⁵ -----	f_c	$0.375 f'_c$ -----	-----	750	938	1, 125	1, 405	1, 875

¹ Plain bars in footing slabs must be anchored by means of standard hooks. The center faces of these hooks, and the ends of deformed bars, must be not less than 3 inches nor more than 6 inches from the face of the footing. In isolated footings the shearing unit stress on the critical section shall not exceed $0.03 f'_c$, nor in any case shall it exceed 75 pounds per square inch. The critical section for shear to be used as a measure of diagonal tension shall be assumed as a vertical section obtained by passing a series of vertical planes through the footing, each of which is parallel to a corresponding face of the column, pedestal, or wall, and located a distance therefrom equal to the depth d for footings on soil, and one-half the depth d for footings on piers.

² A deformed bar is a reinforcing bar conforming to A.S.T.M. specifications A305. Wire mesh with welded intersections not farther apart than 6 inches in the direction of the principal reinforcement, and with cross wires not smaller than No. 10 A. S. & W. gage, may be rated as a deformed bar.

³ Top bars, in reference to bond, are horizontal bars so placed that not more than 12 inches of concrete is east in the member below the bar.

⁴ Reinforcement which does not conform to the definition of a deformed bar shall be classed as a plain bar.

⁵ This increase shall be permitted only when the least distance between the edges of the loaded and unloaded areas is a minimum of $\frac{1}{4}$ of the parallel side dimension of the loaded area. The allowable bearing stress on a reasonable concentric area greater than $\frac{1}{4}$ but less than the full area shall be interpolated between the values given.

Data extracted from Journal of the American Concrete Institute, May 1956. Reprints by permission of American Concrete Institute.

inch. For cast-iron sections, 10,000 pounds per square inch. For steel-pipe columns filled with concrete, the allowable load is determined by the formula—

$$P=0.25f'_c\left(1-0.000025\frac{h^2}{K_c^2}\right)A_c+f'_sA_s$$

Where P =allowable loads, lbs.

f'_c =compressive strength of concrete at 28 days unless otherwise specified, psi.

h =unsupported length of column, in.

K_c =radius of gyration of concrete in pipe column.

A_c =net area of concrete section, sq. in.

A_s =effective cross-sectional area of reinforcement in compression in column, sq. in.

f'_s is given by the formula—

$$f'_s=17,000-0.485\frac{h^2}{K_s^2}$$

when the pipe has a yield strength of at least 33,000 pounds per square inch and an h/K_s ratio not exceeding 120; K_s being the radius of gyration of the steel-pipe section.

- (4) *Compression, flexural members.* To approximate the effect of creep, the stress in compression reinforcement resisting bending may be taken at twice the value indicated by using the straight-line relation between stress and strain, and the modular ratio given in 164c(2) above, but not of greater value than the allowable stress in tension.

e. Values for n . n , the ratio of the modulus of elasticity of steel to that of concrete, may be taken as 30,000 divided by the ultimate compressive strength of a given concrete at 28 days.

165. Weights, Areas, and Spacing of Reinforcing Bars

a. Weights and areas of plain steel bars are given in paragraph 150.

b. The designations, unit weights, and nominal dimensions of A.S.T.M. standard deformed reinforcing bars are given in table 172.

c. Table 173 shows the areas and perimeters of various combinations of four bars, using the nomenclature and dimensions of table 172.

Table 172. A.S.T.M. Standard Deformed Reinforcing Bars

Bar designation number ¹	Unit weight (pounds per foot)	Nominal dimensions		
		Diameter (inches)	Cross-sectional area (square inches)	Perimeter (inches)
2 ² -----	0. 167	0. 250	0. 05	0. 786
3 -----	. 376	. 375	. 11	1. 178
4 -----	. 668	. 500	. 20	1. 571
5 -----	1. 043	. 625	. 31	1. 963
6 -----	1. 502	. 750	. 44	2. 356
7 -----	2. 044	. 875	. 60	2. 749
8 -----	2. 670	1. 000	. 79	3. 142
9 ³ -----	3. 400	1. 128	1. 00	3. 544
10 ³ -----	4. 303	1. 270	1. 27	3. 990
11 ³ -----	5. 313	1. 410	1. 56	4. 430

¹ Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars. The nominal diameter of a deformed bar is equivalent to the diameter of a plain bar having the same weight per foot as the deformed bar.

² $\frac{1}{4}$ -inch bar in plain round only.

³ Bars of designations numbers 9, 10, and 11 correspond to the former 1-inch-square, $1\frac{1}{4}$ -inch-square, and $1\frac{1}{2}$ -inch-square sizes and are equivalent to those former standard bar sizes in weight and nominal cross-sectional areas.

The above table including the footnotes is reprinted from "Tentative Specifications for Billet-Steel Bars for Concrete Reinforcement, A.S.T.M. Designation A15-58T," revision of February 1959 by permission of the American Society for Testing Materials, and is in agreement with U.S. Department of Commerce Simplified Practice Recommendation 26-50 covering Steel Reinforcing Bars.

Table 173. Bar Areas and Perimeters

Area (square inches)	Perimeter (inches)	A.S.T.M. bar designations					
		4	5	6	7	8	9
0.79 -----	6. 3	4					
0.90 -----	6. 7	3	1				
1.01 -----	7. 1	2	2				
1.12 -----	7. 5	1	3				
1.23 -----	7. 8		4				
1.36 -----	8. 2		3	1			
1.50 -----	8. 6		2	2			
1.52 -----	8. 6		3		1		
1.63 -----	9. 0		1	3			
1.77 -----	9. 4			4			
1.82 -----	9. 4		2		2		
1.93 -----	9. 8			3	1		
2.09 -----	10. 2			2	2		
2.11 -----	10. 2			3		1	
2.11 -----	10. 2		1		3		
2.25 -----	10. 6			1	3		
2.32 -----	11. 1			3			1
2.40 -----	11. 0				4		
2.45 -----	11. 0			2		2	
2.59 -----	11. 4				3	1	
2.77 -----	11. 8				2	2	
2.80 -----	11. 8			1		3	

Table 173. Bar Areas and Perimeters—Continued

Area (square inches)	Perimeter (inches)	A.S.T.M. bar designations					
		6	7	8	9	10	11
2.80	11.8		3		1		
2.88	11.8	2			2		
2.96	12.2		1	3			
3.07	12.2		3			1	
3.14	12.6			4			
3.20	12.6		2		2		
3.37	13.0			3	1		
3.44	13.0	1			3		
3.58	13.4			2	2		
3.60	13.4		1		3		
3.64	13.4			3		1	
3.74	13.5		2			2	
3.79	13.8			1	3		
3.93	13.9			3			1
4.00	14.2				4		
4.12	14.3			2		2	
4.27	14.6				3	1	
4.41	14.8		1			3	
4.56	15.1				3		1
4.60	15.1			1		3	
4.64	15.1				2	2	
4.70	15.1			2			2
4.81	15.5				1	3	
5.08	16.0					4	
5.12	15.9				2		2
5.37	16.4					3	1
5.47	16.4			1			3
5.66	16.8					2	2
5.95	17.3					1	3
6.24	17.7						4

d. Minimum Spacings and Clearances for Beam Reinforcing Bars. These are shown in figure 81. The horizontal distances AB and CD between reinforcing bars are either 1 inch, $1\frac{1}{3}$ times maximum aggregate size, or 1-bar diameter, whichever is largest.

e. Concrete Protection for Reinforcement. The following are the provisions of the ACI Building Code on this subject:¹

- (1) The reinforcement of footings and other principal structural members in which the concrete is deposited against the ground shall have not less than 3 inches of concrete between it and the ground contact surface. If concrete surfaces after removal of the forms are to be exposed to the weather

¹ Quoted from pars. 506 and 1303 of "Building Code Requirements for Reinforced Concrete" adopted as a standard by the American Concrete Institute in 1956.

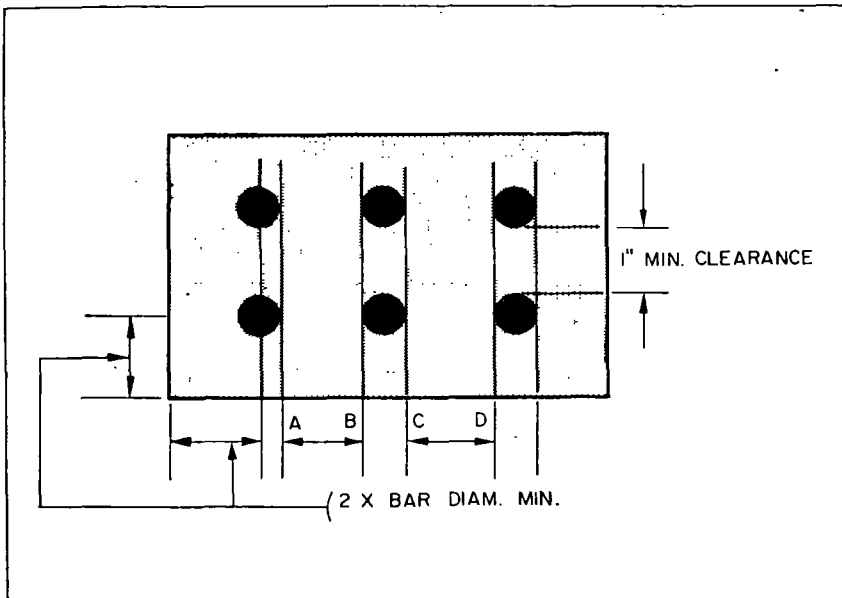


Figure 81. Minimum spacings and clearances for beam reinforcing bars.

- or be in contact with the ground, the reinforcement shall be protected by not less than 2 inches of concrete for bars larger than #5 and $1\frac{1}{2}$ inches for #5 bars or smaller.
- (2) The concrete protective covering for reinforcement at surfaces not exposed directly to the ground or weather shall be not less than $\frac{3}{4}$ inch for slabs and walls; and not less than $1\frac{1}{2}$ inches for beams, girders, and columns. In concrete joist floors in which the clear distance between joists is not more than 30 inches, the protection of reinforcement shall be at least $\frac{3}{4}$ inch.
 - (3) If the general code of which this code forms a part specifies, as fire protective covering of the reinforcement, thicknesses of concrete greater than those given (herein), then such greater thicknesses shall be used.
 - (4) Concrete protection for reinforcement shall in all cases be at least equal to the diameter of bars.
 - (5) Exposed reinforcing bars intended for bonding with future extensions shall be protected from corrosion by concrete or other adequate covering.
 - (6) (For precast concrete): At surfaces not exposed to weather, all reinforcement shall be protected by concrete equal to the nominal diameter of bars but not less than $\frac{5}{8}$ inch.

166. Standard Notation for Beam Formulas

A_s = area of reinforcing bars in square inches

b = width of rectangular beam, or of slab or T-beam, in inches

b' = width of stem of T-beam, in inches

d = depth of beam to center of tension reinforcing, in inches

f_c = compressive unit stress in concrete in pounds per square inch

f'_c = ultimate compressive strength of 28-day concrete, in pounds per square inch

f_s = Tensile stress in reinforcing in pounds per square inch

j = ratio of distance (jd) between resultant of compressive and tensile stresses to effective depth

jd = arm of resisting couple; $j = 1 - \frac{k}{3}$ for rectangular bars

k = ratio of distance (kd or kt) between extreme fiber and neutral axis to effective depth or to total depth

kd = depth of beam to neutral axis in inches

K = coefficient of resistance beam $\frac{M}{bd^2}$

M = moment of resistance, or bending moment, $= \frac{1}{8}$ WL for simple, uniformly loaded beams

$n = E_s/E_c$: taken as $\frac{30,000}{\text{ultimate 28-day compressive strength of concrete}}$

p = percentage of reinforcing $= \frac{A_s}{bd}$

t = overall dimension of column in inches; also depth of flange

v = shearing stress in pounds per square inch $= \frac{V}{bjd}$ for rectangular beams; $\frac{V}{b'jd}$ for T-beams

V = Total shear in pounds

z = ratio of distance (zkd) between extreme fiber and resultant of compressive stresses to distance kd

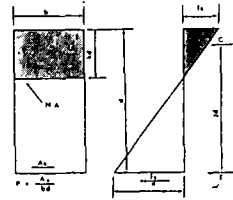
167. Design Data for Slabs and Rectangular Beams

The following data apply to rectangular beams with tension reinforcing, and to slabs reinforced in one direction when designed as rectangular beams 1 foot wide:

a. Coefficients K, k, j, p for rectangular beams:

Table 174. Coefficients (K, k, j, p) for Rectangular Sections

f'_c and n	f_c	K	k	j	p	K	k	j	p
		$f_s = 8,000 \quad a = 0.53$				$f_s = 10,000 \quad a = 0.68$			
2000	700	161	0.568	0.811	0.0249	149	0.512	0.830	0.0179
	750	177	.584	.806	.0274	163	.529	.824	.0198
	800	192	.600	.800	.0300	179	.546	.818	.0218
	900	224	.628	.791	.0353	209	.574	.809	.0258
15	1000	255	.652	.783	.0408	240	.600	.800	.0300
	1200	320	.693	.769	.0520	303	.643	.786	.0386
2500	875	202	.568	.811	.0311	186	.512	.830	.0224
	950	225	.588	.804	.0349	208	.533	.823	.0253
	1000	240	.600	.800	.0375	223	.546	.818	.0273
	1125	280	.628	.791	.0442	261	.574	.809	.0323
12	1250	319	.652	.783	.0509	300	.600	.800	.0375
	1500	400	.693	.769	.0650	379	.643	.786	.0482
3000	1050	242	.568	.811	.0373	223	.512	.830	.0269
	1125	265	.584	.806	.0411	245	.529	.824	.0298
	1200	288	.600	.800	.0450	268	.546	.818	.0328
	1350	335	.628	.791	.0530	313	.574	.809	.0387
10	1500	383	.652	.783	.0611	360	.600	.800	.0450
	1800	480	.693	.769	.0780	455	.643	.786	.0579
3750	1300	298	.565	.812	.0459	275	.510	.830	.0332
	1400	329	.583	.806	.0510	305	.528	.824	.0370
	1500	360	.600	.800	.0563	335	.546	.818	.0410
	1700	423	.630	.790	.0669	396	.576	.808	.0490
8	1875	479	.652	.783	.0764	450	.600	.800	.0563
	2250	600	.693	.769	.0975	568	.643	.786	.0723



$$k = \frac{1}{1 + f_s/nf_c}$$

$$j = 1 - \frac{1}{3}k$$

$$p^* = \frac{fc}{2f_s} \times k$$

$$K = \frac{fc}{2}kj$$

$$a = \frac{fs}{12,000} \times (\text{average } j\text{-value})$$

$$\text{for use in } A_s = \frac{M}{ad} \text{ or } A_s = \frac{NE}{adi}$$

5000	1500	327	.529	.824	.0496	299	.474	.842	.0356				
	1750	403	.568	.811	.0621	371	.512	.829	.0448				
	2000	480	.600	.800	.0750	446	.545	.818	.0545				
	2250	559	.628	.791	.0883	522	.574	.809	.0646				
	2500	638	.652	.783	.1019	600	.600	.800	.0750				
	3000	799	.692	.770	.1298	758	.643	.786	.0965				
										<i>K</i>	<i>k</i>	<i>f</i>	<i>p</i>
		$f_s=12,000 \quad a=0.83$				$f_s=14,000 \quad a=0.98$				$f_s=16,000 \quad a=1.13$			
2000	700	138	.467	.844	.0136	129	.429	.857	.0107	120	.396	.868	.0087
	750	152	.484	.839	.0151	142	.446	.851	.0119	133	.413	.862	.0097
	800	167	.500	.833	.0167	156	.462	.846	.0132	147	.429	.857	.0107
	900	196	.529	.824	.0198	185	.491	.836	.0158	175	.458	.847	.0129
15	1000	227	.556	.815	.0232	214	.517	.828	.0185	203	.484	.839	.0151
	1200	288	.600	.800	.0300	274	.563	.812	.0241	262	.529	.824	.0198
2500	875	173	.467	.844	.0170	161	.429	.857	.0134	150	.396	.868	.0108
	950	194	.487	.838	.0193	181	.449	.850	.0152	170	.416	.861	.0124
	1000	208	.500	.833	.0208	195	.462	.846	.0165	184	.429	.857	.0134
	1125	246	.529	.825	.0248	231	.491	.836	.0197	218	.458	.847	.0161
12	1250	283	.556	.815	.0290	268	.517	.828	.0231	254	.484	.839	.0189
	1500	360	.600	.800	.0375	343	.563	.812	.0302	327	.529	.824	.0248
3000	1050	207	.467	.844	.0204	193	.429	.857	.0161	180	.396	.868	.0130
	1125	229	.484	.839	.0227	213	.446	.851	.0179	200	.413	.862	.0145
	1200	250	.500	.833	.0250	235	.462	.846	.0198	221	.429	.857	.0161
	1350	294	.529	.824	.0298	277	.491	.836	.0237	262	.458	.847	.0193
10	1500	340	.556	.815	.0348	321	.517	.828	.0277	305	.484	.839	.0227
	1800	432	.600	.800	.0450	411	.563	.812	.0362	392	.529	.824	.0298

***Balanced steel ratio" applies to problems involving bending only.

Table 174. Coefficients (K, k, j, p) for Rectangular Sections—Continued

$f'e$ and n	f_e	K	k	j	p	K	k	j	p	K	k	j	p
		$f_s=12,000 \quad a=0.83$				$f_s=14,000 \quad a=0.98$				$f_s=16,000 \quad a=1.13$			
3750	1300	255	.464	.845	.0251	238	.426	.858	.0198	223	.394	.869	.0160
	1400	284	.483	.839	.0282	265	.444	.852	.0222	249	.412	.863	.0180
	1500	312	.500	.833	.0313	293	.461	.846	.0247	276	.429	.857	.0201
	1700	371	.531	.823	.0376	350	.493	.836	.0299	331	.460	.847	.0244
	1875	425	.556	.815	.0434	401	.517	.828	.0346	381	.484	.839	.0284
	2250	540	.600	.800	.0563	514	.562	.813	.0452	490	.529	.824	.0372
5000	1500	276	.429	.857	.0268	255	.391	.870	.0209	238	.360	.880	.0169
	1750	345	.467	.844	.0341	322	.429	.857	.0268	301	.396	.868	.0217
	2000	417	.500	.833	.0417	391	.462	.846	.0330	368	.429	.857	.0268
	2250	490	.529	.824	.0496	462	.491	.836	.0395	436	.458	.847	.0322
	2500	566	.556	.815	.0579	535	.517	.828	.0462	508	.484	.839	.0378
	3000	720	.600	.800	.0750	686	.563	.812	.0603	654	.529	.824	.0496
2000	700	113	0.368	0.877	0.0072	107	0.344	0.885	0.0060	101	0.323	0.892	0.0051
	750	126	.385	.872	.0080	119	.360	.880	.0068	112	.338	.887	.0058
	800	139	.400	.867	.0089	131	.375	.875	.0075	125	.353	.882	.0064
	900	165	.429	.857	.0107	157	.403	.866	.0091	149	.380	.873	.0078
	1000	193	.455	.848	.0126	184	.429	.857	.0107	175	.405	.865	.0092
	1200	250	.500	.833	.0167	239	.474	.842	.0142	230	.450	.850	.0123

2500	875	141	.368	.877	.0089	133	.344	.885	.0075	126	.323	.892	.0064
	950	161	.388	.871	.0102	152	.363	.879	.0086	144	.341	.886	.0074
	1000	173	.400	.867	.0111	164	.375	.875	.0094	156	.353	.882	.0080
	1125	207	.429	.857	.0134	196	.403	.866	.0113	187	.380	.873	.0097
12	1250	241	.455	.848	.0158	230	.429	.857	.0134	219	.405	.865	.0115
	1500	312	.500	.833	.0208	299	.474	.842	.0178	287	.450	.850	.0153
3000	1050	169	.368	.877	.0107	160	.344	.885	.0090	151	.323	.892	.0077
	1125	189	.385	.872	.0120	178	.360	.880	.0101	169	.338	.887	.0086
	1200	208	.400	.867	.0133	197	.375	.875	.0113	187	.353	.882	.0096
	1350	248	.429	.857	.0161	236	.403	.866	.0136	224	.380	.873	.0117
10	1500	289	.455	.848	.0190	276	.429	.857	.0161	263	.405	.865	.0138
	1800	375	.500	.833	.0250	359	.474	.842	.0213	344	.450	.850	.0184
3750	1300	209	.366	.878	.0132	197	.342	.886	.0111	186	.321	.893	.0095
	1400	234	.384	.872	.0149	221	.359	.880	.0126	209	.337	.888	.0107
	1500	260	.400	.867	.0167	246	.375	.875	.0141	234	.353	.882	.0120
	1700	313	.430	.857	.0203	298	.405	.865	.0172	283	.382	.873	.0148
8	1875	362	.455	.848	.0237	345	.429	.857	.0201	328	.405	.865	.0173
	2250	469	.500	.833	.0313	449	.474	.842	.0267	430	.450	.850	.0230
5000	1500	222	.333	.889	.0139	209	.310	.897	.0116	196	.290	.903	.0099
	1750	282	.368	.877	.0179	266	.344	.889	.0150	252	.323	.892	.0128
	2000	347	.400	.867	.0222	328	.375	.875	.0188	311	.353	.882	.0160
	2250	414	.429	.857	.0268	393	.403	.866	.0227	373	.380	.873	.0194
6	2500	482	.455	.848	.0316	460	.429	.857	.0268	438	.405	.865	.0230
	3000	625	.500	.833	.0417	599	.474	.842	.0356	574	.450	.850	.0307

Table 174. Coefficients (K, k, j, p) for Rectangular Sections—Continued

$f'e$ and n	fc	K	k	j	p	K	k	j	p	K	k	j	p
		$fs=24,000 \quad \alpha=1.76$				$fs=27,000 \quad \alpha=2.00$				$fs=30,000 \quad \alpha=2.24$			
2000	700	96	.304	.899	.0044	89	.280	.907	.0036	83	.259	.914	.0030
	750	107	.319	.894	.0050	99	.294	.902	.0041	93	.273	.909	.0034
	800	118	.333	.889	.0055	111	.308	.897	.0046	104	.286	.905	.0038
	900	143	.360	.880	.0067	133	.333	.889	.0055	125	.310	.897	.0047
	1000	168	.385	.872	.0080	157	.357	.881	.0066	148	.333	.889	.0055
15	1200	220	.429	.857	.0107	208	.400	.867	.0089	197	.375	.875	.0075
2500	875	120	.304	.899	.0055	111	.280	.907	.0045	104	.259	.914	.0038
	950	137	.322	.893	.0064	127	.297	.901	.0052	119	.275	.908	.0044
	1000	148	.333	.889	.0069	138	.308	.897	.0057	129	.286	.905	.0048
	1125	178	.360	.880	.0084	167	.333	.889	.0069	156	.310	.897	.0058
	1250	210	.385	.872	.0100	197	.357	.881	.0083	185	.333	.889	.0069
12	1500	276	.429	.857	.0134	260	.400	.867	.0111	246	.375	.875	.0094
3000	1050	143	.304	.899	.0067	133	.280	.907	.0054	124	.259	.914	.0045
	1125	160	.319	.894	.0075	149	.294	.902	.0061	140	.273	.909	.0051
	1200	178	.333	.889	.0083	166	.308	.897	.0068	155	.286	.905	.0057
	1350	214	.360	.880	.0101	200	.333	.889	.0083	188	.310	.897	.0070
	1500	252	.385	.872	.0120	236	.357	.881	.0099	222	.333	.889	.0083
10	1800	331	.429	.857	.0161	312	.400	.867	.0133	295	.375	.875	.0113
3750	1300	176	.302	.899	.0082	164	.278	.907	.0067	153	.257	.914	.0056
	1400	199	.318	.894	.0093	185	.293	.902	.0076	173	.272	.909	.0063
	1500	222	.333	.889	.0104	207	.308	.897	.0086	194	.286	.905	.0071
	1700	270	.362	.879	.0128	253	.335	.888	.0106	238	.312	.896	.0088
	1875	315	.385	.872	.0150	295	.357	.881	.0124	278	.333	.889	.0104
8	2250	414	.429	.857	.0201	390	.400	.867	.0166	369	.375	.875	.0141

5000	1500	186	. 273	. 909	. 0085	172	. 250	. 917	. 0069	160	. 231	. 923	. 0058
	1750	239	. 304	. 899	. 0111	222	. 280	. 907	. 0091	207	. 259	. 914	. 0076
	2000	296	. 333	. 889	. 0139	276	. 308	. 897	. 0114	259	. 286	. 905	. 0095
	2250	356	. 360	. 880	. 0169	333	. 333	. 889	. 0139	313	. 310	. 897	. 0116
6	2500	420	. 385	. 872	. 0201	393	. 357	. 881	. 0165	370	. 333	. 889	. 0139
	3000	551	. 429	. 857	. 0268	520	. 400	. 867	. 0222	492	. 375	. 875	. 0188

b. Formulas. For beams beyond the scope of table 174, the following formulas are used:

$$(1) k = \frac{nf_c}{nf_c + f_s} \text{ or } \frac{pf_s}{1/2f_c}$$

$$(2) p = \frac{f_c k}{2f_s} \text{ or } \frac{A_s}{bd}$$

$$(3) j = 1 - \frac{k}{3}; jd = d - \frac{kd}{3}$$

$$(4) K = f_s p j \text{ or } \frac{M}{bd^2}; d = \sqrt{\frac{M}{bk}}$$

$$(5) A_s = \frac{M}{f_s j d}$$

168. Design Data for T-Beams

The following data apply to T-beams with adequate web reinforcement, normally provided by bending about one-half of the longitudinal bars and providing stirrups if required.

a. Determination of Width *b.* For T-beams or L-beams, the width *b* may not exceed one-fourth the span length of the beam; and the effective width overhanging on either side of the stem may not exceed one-half the clear distance to the next beam or eight times the slab thickness.

b. Formulas. For beams beyond the scope of table 175, the following formulas are used:

$$(1) k = \frac{1}{1 + \frac{f_s}{nf_c}}; kd = \frac{2nlA_s + bt^2}{2nA_s + 2bt}$$

$$(2) jd = d - z; z = \frac{3kd - 2t}{2kd - t} \times \frac{t}{3}$$

$$(3) K = \frac{M}{bd^2}; A_s = \frac{M}{f_s jd}$$

c. Design Constants. For $n=10$ and $n=15$, and for various values of f_s , f_c , and t/d , values of k and p are given in table 175. Interpolations are made for other values of n , f_s , and f_c .

169. Design of Beam Stirrups¹

a. Area of Steel. The fundamental equation for stirrups is—

$$A_v = \frac{V's}{Bf_v jd}$$

¹ Material in this paragraph is taken, with minor changes in wording, from pp. 22 and 23; formula 30 on p. 96; table 9 on p. 52; diagram 17 on p. 58; and table 15 on p. 57, of the ACI Reinforced Concrete Design Handbook, second edition, 1955.

where—

A_v = total cross-sectional area of stirrup legs

$V = v'bjd$ = total shear to be carried by stirrups

$B = (\sin x \cos x)$ with x = angle between stirrups and axis of beam.

From this—

$$A_v = \frac{v'bs}{Bf_v}, \text{ or } \frac{1}{S} = \frac{v'b}{BA_vf_v}$$

For stirrups perpendicular to the axis of the beam, $B=1$, and the last equation becomes—

$$\frac{1}{S} = \frac{v'b}{A_vf_v}$$

In a rectangular beam or in the stem of a T-beam, the concrete alone is assigned to carry shear up to 3 percent of its 28-day ultimate compressive strength.

b. Number and Spacing. The determination of the number and spacing of stirrups depends on the shape and area of that part of the shear diagram for which stirrups are required. The area of the shear diagram determines the number of stirrups required, while the stirrup spacing depends also on the shape of the diagram. Shear diagrams may be considered of three types—rectangular, trapezoidal, and triangular. Only trapezoidal and triangular shear diagrams offer problems in stirrup spacing, because the spacing is constant for rectangular diagrams. The procedure is as follows:

(1) Select the type of stirrup (vertical or inclined); the total area of stirrup legs A_v (a above); and the allowable steel stress f_v .

(2) Calculate the value $\frac{v'b}{BA_vf_v}$ at the large and small ends of the shear diagram and at points of discontinuity. To obtain the value of j , use figure 82(1).

(3) Calculate S , the length of the base of the shear diagram.

(4) Determine the number and spacing of the stirrups. To do

this, superpose the $\frac{v'b}{BA_vf_v}$ curve on figure 82(2). Read the

stirrup spacing where the curve crosses the heavy vertical lines. The number of stirrups required equals the number of vertical lines intersected.

(5) Check by figure 82(3) for embedment of stirrups.

Table 175. Design Constants, T-Beams

f_s	t/d	$n=15$								$n=10$							
		$f_c=600$		$f_c=700$		$f_c=800$		$f_c=900$		$f_c=750$		$f_c=900$		$f_c=1200$		$f_c=1350$	
		K	p	K	p	K	p	K	p	K	p	K	p	K	p	K	p
16,000	0.06	32	.0021	38	.0024	43	.0028	49	.0032	40	.0025	48	.0032	65	.0042	73	.0047
	.10	50	.0032	58	.0038	67	.0044	76	.0050	60	.0040	75	.0049	100	.0066	114	.0075
	.14	64	.0042	76	.0051	88	.0059	100	.0067	77	.0051	96	.0063	132	.0088	150	.0099
	.18	76	.0051	90	.0061	104	.0071	120	.0081	89	.0061	114	.0076	156	.0107	180	.0122
	.22	84	.0057	100	.0070	118	.0082	136	.0094	98	.0068	126	.0085	177	.0122	204	.0140
	.26	89	.0062	109	.0076	129	.0090	149	.0105	104	.0072	134	.0093	194	.0134	224	.0156
	.30	93	.0066	115	.0082	137	.0098	159	.0113	107	.0074	140	.0098	206	.0145	238	.0169
	.34	95	.0067	118	.0085	142	.0102	166	.0120	-----	-----	142	.0101	213	.0153	249	.0180
	.38	-----	-----	120	.0087	146	.0106	171	.0125	-----	-----	-----	-----	219	.0158	256	.0187
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
18,000	.06	32	.0018	38	.0021	43	.0025	49	.0028	39	.0022	48	.0027	65	.0037	73	.0042
	.10	49	.0028	58	.0034	67	.0039	76	.0044	60	.0035	73	.0043	100	.0058	113	.0066
	.14	62	.0037	74	.0044	86	.0051	99	.0059	75	.0045	93	.0055	130	.0077	148	.0088
	.18	73	.0044	88	.0053	102	.0062	117	.0071	87	.0052	109	.0066	154	.0093	176	.0107
	.22	80	.0049	98	.0060	115	.0071	133	.0082	95	.0057	120	.0074	173	.0106	199	.0123
	.26	85	.0053	105	.0066	125	.0078	145	.0091	98	.0060	128	.0079	188	.0117	218	.0136
	.30	88	.0055	110	.0069	132	.0083	154	.0097	-----	-----	132	.0082	198	.0125	231	.0146
	.34	-----	-----	113	.0071	136	.0087	160	.0103	-----	-----	-----	-----	205	.0130	241	.0154
	.38	-----	-----	-----	-----	138	.0089	164	.0106	-----	-----	-----	-----	207	.0133	246	.0159
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	.06	32	.0016	37	.0019	43	.0022	49	.0025	39	.0020	48	.0024	64	.0033	73	.0038
	.10	48	.0025	57	.0030	66	.0035	75	.0039	58	.0031	72	.0038	99	.0052	113	.0059

20,000	.14	61	.0033	73	.0039	85	.0046	97	.0052	73	.0039	92	.0049	128	.0068	146	.0078
	.18	71	.0038	86	.0047	101	.0055	116	.0063	84	.0045	106	.0057	151	.0082	174	.0095
	.22	78	.0043	95	.0052	113	.0062	130	.0072	90	.0049	117	.0064	169	.0093	195	.0108
	.26	82	.0045	102	.0057	121	.0068	141	.0079	93	.0051	123	.0068	182	.0102	211	.0119
	.30	84	.0046	106	.0059	128	.0072	149	.0085	-----	-----	126	.0070	192	.0108	224	.0127
	.34	-----	-----	107	.0060	130	.0074	154	.0088	-----	-----	-----	-----	196	.0112	231	.0133
	.38	-----	-----	-----	-----	-----	-----	156	.0090	-----	-----	-----	-----	-----	-----	234	.0135

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Values of $j = 1 - \frac{k - \frac{2t}{3d}}{2k - \frac{t}{d}} \times \frac{t}{d}$ and $y = \frac{1 - \frac{2t}{3kd}}{2 - \frac{t}{kd}}$

(a) Enter table with known value of $\frac{t}{d}$ and k ; select j .

(b) Enter table with known value of $\frac{t}{kd}$; select y ; compute $j = 1 - y\frac{t}{d}$.

j	
k	$\frac{t}{d}$
	0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38 0.40
0.20	0.97 0.96 0.96 0.95 0.94 0.94 0.93 0.93 0.92 0.92 0.92 0.91 0.90 0.90 0.89 0.88 0.87 0.87
0.25	0.97 0.96 0.95 0.95 0.94 0.93 0.93 0.92 0.92 0.92 0.91 0.90 0.89 0.89 0.88 0.87 0.87 0.87
0.30	0.97 0.96 0.95 0.94 0.94 0.93 0.92 0.92 0.91 0.91 0.90 0.90 0.89 0.89 0.88 0.87 0.87 0.87
0.35	0.97 0.96 0.95 0.94 0.94 0.93 0.92 0.91 0.91 0.90 0.89 0.89 0.88 0.88 0.87 0.87 0.86 0.85
0.40	0.97 0.96 0.95 0.94 0.93 0.93 0.92 0.91 0.90 0.90 0.89 0.89 0.88 0.88 0.87 0.86 0.85 0.84
0.45	0.97 0.96 0.95 0.94 0.93 0.93 0.92 0.91 0.90 0.89 0.89 0.88 0.88 0.87 0.87 0.86 0.85 0.84
0.50	0.97 0.96 0.95 0.94 0.93 0.93 0.92 0.91 0.90 0.89 0.89 0.88 0.88 0.87 0.86 0.85 0.85 0.84
0.55	0.97 0.96 0.95 0.94 0.93 0.92 0.92 0.91 0.90 0.89 0.88 0.88 0.87 0.86 0.85 0.85 0.84 0.84
0.60	0.97 0.96 0.95 0.94 0.93 0.92 0.92 0.91 0.90 0.89 0.88 0.87 0.87 0.86 0.85 0.85 0.84 0.83

y	
$\frac{t}{kd}$	0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
y	0.49 0.48 0.48 0.47 0.46 0.46 0.45 0.44 0.44 0.43 0.42 0.41 0.40 0.39 0.38 0.36 0.35 0.33

Figure 82(1). Coefficients for T-sections.

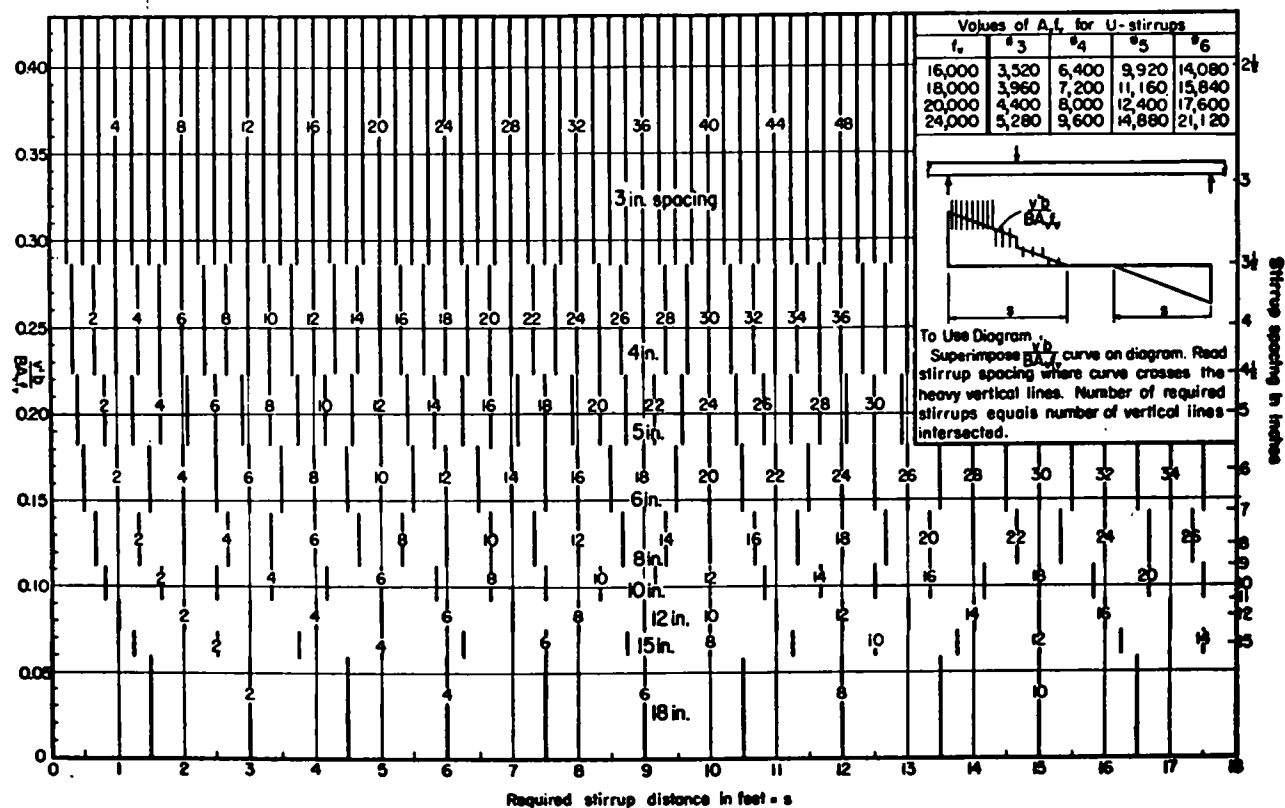
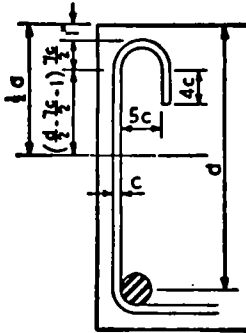


Figure 82(2). Spacing of stirrups.



Values of d

$$\text{Deformed bars } d = (f_v - 10,000) \frac{5c}{f'_c} + 7c + 2$$

$$\text{Plain bars } d = (f_v - 10,000) \frac{11.1c}{f'_c} + 7c + 2$$

When web reinforcement is inclined, determine min. d by multiplying values in table by $\sin x$ (x = angle between tensile and web reinforcement).

	Plain	Deformed				Plain	Deformed				Plain	Deformed			
	#2	#3	#4	#5	#2	#3	#4	#5	#2	#3	#4	#5			
f'_c	$f_v = 12,000$				$f_v = 14,000$				$f_v = 16,000$						
2000	6.5	6.5	8.0	9.5	9.3	8.4	10.5	12.6	12.1	10.3	13.0	15.8			
2500	6.0	6.1	7.5	8.9	8.2	7.6	9.5	11.4	10.4	9.1	11.5	13.9			
3000	5.6	5.9	7.2	8.5	7.5	7.1	8.8	10.5	9.3	8.4	10.5	12.6			
3750	5.2	5.6	6.8	8.0	6.7	6.6	8.2	9.7	8.2	7.6	9.5	11.4			
f'_c	$f_v = 18,000$				$f_v = 20,000$				$f_v = 22,000$						
2000	14.9	12.1	15.5	18.9	17.6	14.0	18.0	22.0	20.4	15.9	20.5	25.1			
2500	12.6	10.6	13.5	16.4	14.9	12.1	15.5	18.9	17.1	13.6	17.5	21.4			
3000	11.2	9.6	12.2	14.7	13.0	10.9	13.8	16.8	14.9	12.1	15.5	18.9			
3750	9.7	8.6	10.8	13.0	11.2	9.6	12.2	14.7	12.6	10.6	13.5	16.4			
f'_c	$f_v = 24,000$				$f_v = 27,000$				$f_v = 30,000$						
2000	23.2	17.8	23.0	28.3	27.3	20.6	26.8	32.9	31.5	23.4	30.5	37.6			
2500	19.3	15.1	19.5	23.9	22.6	17.4	22.5	27.6	26.0	19.6	25.5	31.4			
3000	16.7	13.4	17.2	21.0	19.5	15.3	19.7	24.1	22.3	17.1	22.2	27.2			
3750	14.1	11.6	14.8	18.0	16.3	13.1	16.8	20.5	18.6	14.6	18.8	23.0			

Figure 82(3). Minimum depths for embedment of vertical hooked stirrups.

170. Example of Slab or Rectangular-Beam Design

a. *Problem.* What slab depth and reinforcing are needed for a span of 10 feet, live load of 500 pounds per square foot, using 2,000 pound concrete and Bessemer steel reinforcing good for 18,000 pounds per square inch?

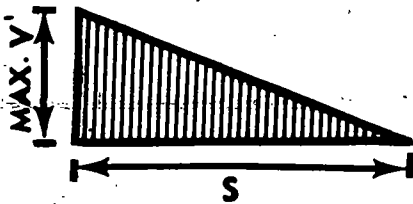
b. *Solution.*

- (1) $n = 30,000 \div 2000 = 15$ (par. 164e)
- (2) $f_c = 2000 \times 0.45 = 900$ psi (par. 164c)
- (3) $b = 12$ inches (section of slab 1 foot wide)
- (4) Assume 8-inch slab thickness (normally 0.8 inch per foot of span)
- (5) Total load $= 500 + (\frac{1}{12} \times 150) = 600$ pounds per square foot
- (6) $M = \frac{1}{8} Wl = \frac{1}{8} (600 \times 10) (10 \times 12) = 90,000$ inch-pounds
- (7) $K = 165.3$; $j = 0.857$; $p = 0.0107$ (par. 167b)

$$(8) d = \sqrt{\frac{M}{bk}} = \sqrt{\frac{90,000}{12 \times 165.3}} = 6.7; \text{ use 8 inches}$$

- (9) $A_s = pbd = 0.0107 \times 12 \times 6.7 = 0.86$ square inch. Adopt #6 bars spaced 6 inches c.-to-c., area = 0.88 square inches per foot of width.

c. *Example (Vertical Stirrups, Triangular Shear Diagram).*



Given:

Max. $v' = 108$ psi;

$S = 8$ ft. 3 in.;

$b = 13$ in.;

$d = 20$ in.;

$f_c = 20,000$ psi;

$f'_c = 3,000$ psi;

No. 3 U-stirrups.

(scale marks are 1-mm each)

From figure 82-B, for $f_c = 20,000$ and No. 3 U-stirrups: $A_v f_c = 4,400$; and $B = 1$ for vertical stirrups.

$$\frac{v'b}{BA_v f_c} = \frac{108 \times 13}{4,400} = 0.319.$$

On figure 82-B, place a straightedge connecting the values of S and $\frac{v'b}{BA_v f_c} = 0.319$ and read the spacing of stirrups where their respective heavy lines cross the straightedge. In case the spacing is greater than the maximum allowable spacing of $\frac{1}{2}d$, use the last spacing permitted until distance S is reached.

Read: 3 at 3 in., 5 at 4 in., 2 at 5 in., 2 at 6 in., 1 at 8 in., 4 at 10 in. Total number of stirrups: $N = 17$.

Refer to figure 82(3) for No. 3 stirrups with $f'_c = 3,000$ psi and $f_c = 20,000$ psi and ascertain that stirrups have sufficient embedment;

$d=10.9$ in. required. If it is desired to locate the first stirrup at half the initial spacing from the end of beam, the $\frac{v'b}{BA_v f_c}$ curve should be shifted horizontally a distance equal to half the initial stirrup spacing.

d. Inclined Stirrups. They are proportioned by the formula—

$$A_v = \frac{V's}{f_c j d (\sin \alpha + \cos \alpha)}$$

Where α =angle between stirrups and axis of beam.

e. Limitation. Stirrups placed perpendicular to the longitudinal reinforcement must not be used alone as web reinforcement when the shearing unit stress (v) exceeds $0.08 f'_c$ or 240 pounds per square inch.

171. Example of T-Beam Design

a. Problem. Design a T-beam for a clear span of 20 feet, slab thickness of 5 inches; total load from slab 400 pounds per square foot, beam spacing 9 feet center to center, 3,000-pound concrete, allowable stress in steel 20,000 pounds per square inch.

b. Solution.

- (1) $n=30,000 \div 3,000=10$ (par. 164e)
- (2) $f_c=3,000 \times 0.45=1,350$ psi (par. 164c)
- (3) $b=60$ inches ($\frac{1}{4}$ span length controls (par. 168a)
- (4) Assume $b'=15$ inches (trial and error)
- (5) Assume $d=13$ inches (trial and error)
- (6) $\frac{t}{d}=\frac{5}{13}=.38$
- (7) $K=234$; $p=0.0135$ (par. 168c)
- (8) Weight of stem $=\frac{12 \times 15}{144} \times 150=188$ pounds per foot
- (9) Total load $=9 \times 400 + 188=3,788$ pounds per foot
- (10) $M=\frac{1}{8} WL=\frac{1}{8} \times 3,788 \times 20 \times 20 \times 12=2,272,800$ inch-pounds
- (11) $d=\sqrt{\frac{M}{bK}}=\sqrt{\frac{2,272,800}{60 \times 234}}=12.7$ inches
- (12) $A_s=pbd=0.0135 \times 60 \times 12.7=10.2$ square inches. Adopt four #11 square bars and four #9 square bars: total area 10.24 square inches (par. 165b).
- (13) Required $b'=13 \times 1\frac{1}{4}=16\frac{1}{4}$ inches. Adopt 16 inches (required for four $1\frac{1}{4}$ -inch bars in one layer, figure 81)
- (14) Total depth of stem below slab $=13\frac{1}{2} + \frac{1}{2} + \frac{5}{8} + (2 \times 1\frac{1}{4})=19\frac{1}{4}$ inches. Adopt 12 inches.
- (15) Design of stirrups—
 - (a) Revised weight—

Load from slab— 400 psf $\times 9$ ft $=3,600$ lbs.

Stem below slab— $\frac{12 \times 16}{144} \times 150 = \frac{200 \text{ lbs.}}{3,800 \text{ lbs/ft}}$

$$(b) V = \frac{1}{2} \times 3,800 \times 20 = 38,000 \text{ lbs.}$$

$$(c) v = \frac{V}{b \times j \times d} \quad b' = 16'' \quad d = 13''.$$

$$1. t/d = 0.38$$

$$2. K = \frac{\frac{nA_s}{bt} + \frac{1}{2} \times t/d}{\frac{nA_s}{bt} + 1} = \frac{\frac{10 \times 10.24}{60 \times 5} + \frac{1}{2} \times 0.38}{\frac{10 \times 10.24}{60 \times 5} + 1} = 0.398$$

3. With $t/d = 0.38$ and $k = 0.398$, enter figure 82(1) and determine $j = 0.87 = 210$ pounds per square inch.

$$(d) \text{ Then } v = \frac{38,000}{16 \times 0.87 \times 13}$$

$$(e) v_c = 0.03 \times 3,000 = 90 \text{ psi}$$

$$(f) v' = 210 - 90 = 120 \text{ psi}$$

(g) From figure 82(2) for $f_v = 20,000$ psi and #3 U-stirrups, $A_v f_v = 4,400$ and $B = 1$ for vertical stirrups, then—

$$\frac{v'b}{BA_v f_v} = \frac{120 \times 16}{1 \times 4,400} = 0.436$$

$$(h) S = \frac{120 \times 10}{210} = 5.71'$$

(i) Enter figure 82-B for—

$$\frac{v'b}{BA_v f_v} = 0.436 \text{ along left side and } S = 5.71' \text{ along the bottom,}$$

choose stirrups as follows—

8 at 3'', 2 at 4'', 2 at 5'', 5 at 6''. (This carries the stirrups past the point where they are required. It should be noted here that, according to figure 82(2), we could have used 8'', 9'', and 10'' spacing, but we are limited to $\frac{1}{2}d$ as a maximum.)

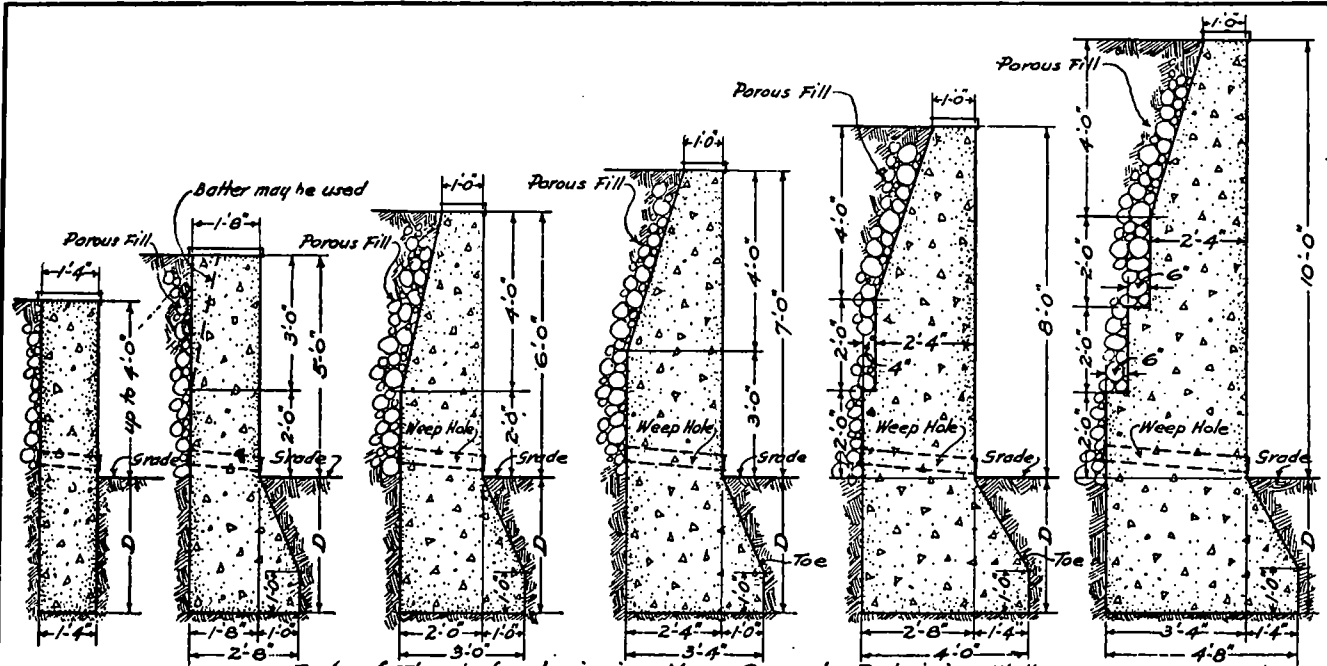
172. Retaining Walls

For average earth pressures and for heights up to 10 feet, cross sections of plain concrete and reinforced concrete are given in figure 83.

Section V. TIMBER

173. Working Stresses

Table 176 shows the allowable unit stresses for stress-graded lumber of certain species and grades. The figures are for normal loading conditions and for peacetime civilian or equivalent military construction. For temporary structures, and for military construction in a theater of operations, the stresses given in the table may be increased by a maximum of 50 percent.



Rule of Thumb for designing Mass Concrete Retaining Walls.

Assume earth level with top of wall. Minimum width at top of wall 1'-0". Width of wall at each step must be $\frac{1}{3}$ of distance from this point to the top of wall. No increase in width required below grade except for toe. For wall without steps minimum width is $\frac{1}{3}$ distance from grade to top. Use same rule for Brick or Rubble retaining walls, except minimum width to be 2'-0" and use $\frac{2}{3}$ in place of $\frac{1}{3}$. Assumed adequate bearing cap of soil $\frac{1}{3}$ of repose. To avoid surface cracks in concrete walls, place $\frac{3}{8}$ " bars 2'-0" o.c. both ways and 2" from the exposed face of the wall. These walls are designed for typical soil conditions with grade not above top of wall. Weep holes of 4" Tile or 2" Brass pipe 10'-0" o.c. Construction joints to be 30'-0" apart.



Figure 83. Concrete retaining walls.

Table 176. Allowable Unit Stresses—Stress-Grade Lumber

Species and commercial grade ^a		Rules under which graded	Allowable unit stresses in pounds per square inch				
			Extreme fiber in bending (f) and tension parallel to grain (t) ^a	Horizontal shear (H)	Compression perpendicular to grain (c1)	Compression parallel to grain (c)	Modulus of elasticity (E)
<i>Ash, white:</i>		National Hardwood Lumber Association.					
2150 f grade.....	J. & P.....		2, 150	145	600	1, 700	1, 650, 000
1900 f grade.....	J. & P.-B. & S.....		1, 900	145	600	1, 500	1, 650, 000
1700 f grade.....	J. & P.-B. & S.....		1, 700	145	600	1, 325	1, 650, 000
1450 f grade.....	J. & P.-B. & S.....		1, 450	120	600	1, 150	1, 650, 000
1300 f grade.....	B. & S.....		1, 300	120	600	1, 050	1, 650, 000
1450 c grade.....	P. & T.....				600	1, 450	1, 650, 000
1200 c grade.....	P. & T.....				600	1, 200	1, 650, 000
1075 c grade.....	P. & T.....				600	1, 075	1, 650, 000
<i>Beech:</i>		National Hardwood Lumber Association.					
<i>Birch:</i>							
2150 f grade.....	J. & P.....		2, 150	145	600	1, 750	1, 760, 000
1900 f grade.....	J. & P.-B. & S.....		1, 900	145	600	1, 525	1, 760, 000
1700 f grade.....	J. & P.-B. & S.....		1, 700	145	600	1, 350	1, 760, 000
1450 f grade.....	J. & P.-B. & S.....		1, 450	120	600	1, 150	1, 760, 000
1550 c grade.....	P & T.....				600	1, 550	1, 760, 000
1450 c grade.....	P & T.....				600	1, 450	1, 760, 000
1200 c grade.....	P & T.....				600	1, 200	1, 760, 000

<i>Chestnut:</i>		National Hardwood Lumber Association.	1, 450	120	360	1, 200	1, 100, 000
1450 f grade.....	J. & P.....						
1200 f grade.....	J. & P.-B. & S.....						
1075 c grade.....	P. & T.....						
<i>Cypress, southern, coast type (tidewater red):</i>		Southern Cypress Manu- facturers' Association.	1, 700	145	360	1, 425	1, 320, 000
1700 f grade.....	J. & P.-B. & S.....						
1300 f grade.....	J. & P.-B. & S.....						
1450 c grade.....	P. & T.....						
1200 c grade.....	P. & T.....						
<i>Cypress, southern, inland type:</i>		National Hardwood Lumber Association.	1, 700	145	360	1, 425	1, 320, 000
1700 f grade.....	J. & P.-B. & S.....						
1300 f grade.....	J. & P.-B. & S.....						
1450 c grade.....	P. & T.....						
1200 c grade.....	P. & T.....						
<i>Douglas fir, coast region:</i>		West Coast Lumber Inspection Bureau.	2, 050	c f h 120	455	1, 500	1, 760, 000
Dense select structural.....	LF.....						
Select structural.....	LF.....						
1500 f industrial.....	LF.....						
1200 f industrial.....	LF.....						
Dense select structural ^b			2, 050	c f h 120	455	1, 650	1, 760, 000
Select structural.....	J. & P.....		1, 900	c f h 120	415	1, 500	1, 760, 000
Dense construction ^b	J. & P.....		1, 750	c g h 120	455	1, 400	1, 760, 000
Construction.....	J. & P.....		1, 500	c g h 120	390	1, 200	1, 760, 000
Standard.....	J. & P.....		1, 200	c g h 95	390	1, 000	ⁱ 1, 760, 000

See footnotes at end of table.

Table 176. Allowable Unit Stresses—Stress-Grade Lumber—Continued

Species and commercial grade ^a		Rules under which graded	Allowable unit stresses in pounds per square inch				
			Extreme fiber in bending (f) and tension parallel to grain (t) ^e	Horizontal shear (H)	Compression perpendicular to grain (c1)	Compression parallel to grain (c)	Modulus of elasticity (E)
<i>Douglas fir, coast region—Con.</i>							
Dense select structural ^b	B. & S.	West Coast Lumber Inspection Bureau.	2, 050	120	455	1, 500	1, 760, 000
Select structural.....	B. & S.		1, 900	120	415	1, 400	1, 760, 000
Dense construction ^b	B. & S.		1, 750	120	455	1, 200	1, 760, 000
Construction.....	B. & S.		1, 500	120	390	1, 000	1, 760, 000
Dense select structural ^b	P. & T.		1, 900	120	455	1, 650	1, 760, 000
Select structural.....	P. & T.		1, 750	120	415	1, 500	1, 760, 000
Dense construction ^b	P. & T.		1, 500	120	455	1, 400	1, 760, 000
Construction.....	P. & T.		1, 200	120	390	1, 200	1, 760, 000
<i>Douglas fir, inland region:</i>							
Select structural ^b	J. & P. ^d	Western Pine Association.	2, 150	145	455	1, 750	1, 760, 000
Structural.....	J. & P. ^d		1, 900	100	400	1, 400	1, 650, 000
Common structural.....	J. & P. ^d		1, 450	95	380	1, 250	1, 650, 000
Select structural ^b	P. & T.				455	1, 750	1, 760, 000
Structural.....	P. & T.				400	1, 400	1, 650, 000
Common structural.....	P. & T.				380	1, 250	1, 650, 000

<i>Elm, rock:</i>							
2150 f grade.....	J. & P.....	National Hardwood Lumber Association.	2, 150	145	600	1, 750	1, 430, 000
1900 f grade.....	J. & P.-B. & S.....		1, 900	145	600	1, 525	1, 430, 000
1700 f grade.....	J. & P.-B. & S.....		1, 700	145	600	1, 350	1, 430, 000
1450 f grade.....	J. & P.-B. & S.....		1, 450	120	600	1, 150	1, 430, 000
1550 c grade.....	P. & T.....				600	1, 550	1, 430, 000
1450 c grade.....	P. & T.....				600	1, 450	1, 430, 000
1200 c grade.....	P. & T.....				600	1, 200	1, 430, 000
<i>Elm, soft; Gum, black and red; Tupelo:</i>							
1700 f grade.....	J. & P.....	National Hardwood Lumber Association.	1, 700	120	300	1, 225	1, 320, 000
1450 f grade.....	J. & P.-B. & S.....		1, 450	120	300	1, 050	1, 320, 000
1200 f grade.....	J. & P.-B. & S.....		1, 200	120	300	875	1, 320, 000
1075 c grade.....	P. & T.....				300	1, 075	1, 320, 000
<i>Hemlock, eastern:</i>							
Select structural.....	J. & P.-B. & S. ^d	Northern Hemlock and Hardwood Manufac- turers' Association.	1, 300	85	360	850	1, 210, 000
Prime structural.....	J. & P. ^{d n}		1, 200	60	360	775	1, 210, 000
Common structural.....	J. & P. ^{d n}		1, 100	60	360	650	1, 210, 000
Utility structural.....	J. & P. ^{d n}		950	60	360	600	1, 210, 000
Select structural.....	P. & T.....				360	850	1, 210, 000
<i>Hemlock; West Coast:</i>							
Select structural.....	LF.....		1, 600	o f l 100	365	1, 100	1, 540, 000
1500 f industrial.....	LF.....		1, 500	100	365	1, 000	1, 540, 000
1200 f industrial.....	LF.....		1, 500	80	365	900	1, 540, 000
Select structural.....	J. & P.....	West Coast Lumber Inspection Bureau.	1, 600	o f l 100	365	1, 200	1, 540, 000
Construction.....	J. & P.....		1, 500	o k l 100	365	1, 100	1, 540, 000
Standard.....	J. & P.....		1, 200	o k l 80	365	1, 000	1, 540, 000

See footnotes at end of table.

Table 176. Allowable Unit Stresses—Stress-Grade Lumber—Continued

Species and commercial grade ^a		Rules under which graded	Allowable unit stresses in pounds per square inch				
			Extreme fiber in bending (f) and tension parallel to grain (t) ^e	Horizontal shear (H)	Compression perpendicular to grain (ci)	Compression parallel to grain (c)	Modulus of elasticity (E)
<i>Hemlock: West Coast—Con.</i>		West Coast Lumber Inspection Bureau.					
Construction.....	B. & S.....		1, 500	m 100	365	1, 000	1, 540, 000
Construction.....	P. & T.....		1, 200	m 100	365	1, 100	1, 540, 000
<i>Hickory, Pecan:</i>		National Hardwood Lumber Association.					
2150 f grade.....	J. & P.-B. & S..		2, 150	145	720	1, 725	1, 980, 000
1900 f grade.....	J. & P.-B. & S..		1, 900	145	720	1, 550	1, 980, 000
1700 f grade.....	J. & P.-B. & S..		1, 700	145	720	1, 350	1, 980, 000
1550 c grade.....	P. & T.....		-----	-----	720	1, 550	1, 980, 000
1450 c grade.....	P. & T.....		-----	-----	720	1, 450	1, 980, 000
1325 c grade.....	P. & T.....		-----	-----	720	1, 325	1, 980, 000
<i>Larch:</i>		Western Pine Association.					
Select structural ^b	J. & P. ^d		2, 150	145	455	1, 750	1, 650, 000
Structural.....	J. & P. ^d		1, 900	120	415	1, 450	1, 650, 000
Common structural.....	J. & P. ^d		1, 450	120	390	1, 325	1, 650, 000
Select structural ^b	P. & T.....		-----	-----	455	1, 750	1, 650, 000
Structural.....	P. & T.....		-----	-----	415	1, 450	1, 650, 000
Common structural.....	P. & T.....		-----	-----	390	1, 325	1, 650, 000

<i>Maple, hard:</i>			National Hardwood Lumber Association.																
2150 f grade.....	J. & P.....	2, 150							145	600	1, 750	1, 760, 000							
1900 f grade.....	J. & P.-B. & S.....	1, 900							145	600	1, 525	1, 760, 000							
1700 f grade.....	J. & P.-B. & S.....	1, 700							145	600	1, 350	1, 760, 000							
1450 f grade.....	J & P.-B. & S.....	1, 450							120	600	1, 150	1, 760, 000							
1550 c grade.....	P. & T.....									600	1, 550	1, 760, 000							
1450 c grade.....	P. & T.....									600	1, 450	1, 760, 000							
1200 c grade.....	P. & T.....									600	1, 200	1, 760, 000							
<i>Pine, southern:</i> °			Southern Pine Inspection Bureau.																
Dense structural 86	2 inches thick only.																		
KD. ^b ^a r																			
Dense structural 72									2, 500	150	455	1, 950	1, 760, 000						
KD. ^b ^a r																			
Dense structural 65									2, 250	135	455	1, 800	1, 760, 000						
KD. ^b ^a r																			
Dense structural 58									2, 050	120	455	1, 650	1, 760, 000						
KD. ^b ^a r																			
No. 1 dense KD ^b ^a r.....									2, 050	135	455	1, 750	1, 760, 000						
No. 1 KD ^a									1, 750	135	390	1, 500	1, 760, 000						
No. 2 dense KD ^b ^a r.....									1, 750	120	455	1, 300	1, 760, 000						
No. 2 KD ^a									1, 500	120	390	1, 100	1, 760, 000						
Dense structural 86. ^b r.....									2, 900	150	455	2, 200	1, 760, 000						
Dense structural 72. ^b r.....									2, 350	135	455	1, 800	1, 760, 000						
Dense structural 65. ^b r.....									2, 050	120	455	1, 600	1, 760, 000						
Dense structural 58. ^b r.....									1, 750	105	455	1, 450	1, 760, 000						
No. 1 dense ^b r.....									1, 750	120	455	1, 550	1, 760, 000						
No. 1.....									1, 500	120	390	1, 350	1, 760, 000						
No. 2 dense ^b r.....									1, 400	105	455	1, 050	1, 760, 000						
No. 2.....									1, 200	105	390	900	1, 760, 000						

See footnotes at end of table.

Table 176. Allowable Unit Stresses—Stress-Grade Lumber—Continued

Species and commercial grade ^a		Rules under which graded	Allowable unit stresses in pounds per square inch				
			Extreme fiber in bending (f) and tension parallel to grain (t) ^e	Horizontal shear (H)	Compression perpendicular to grain (c) ^f	Compression parallel to grain (c) ^g	Modulus of elasticity (E)
<i>Pine, southern</i> —Continued ^o		Southern Pine Inspection Bureau.					
Dense structural 86. ^b r.-----	3 inches and 4 inches thick.		2, 900	150	455	2, 200	1, 760, 000
Dense structural 72. ^b r.-----			2, 350	135	455	1, 800	1, 760, 000
Dense structural 65. ^b r.-----			2, 050	120	455	1, 600	1, 760, 000
Dense structural 58. ^b r.-----			1, 750	105	455	1, 450	1, 760, 000
No. 1 dense SR ^b r.-----			1, 750	120	455	1, 750	1, 760, 000
No. 1 SR-----			1, 500	120	390	1, 500	1, 760, 000
No. 2 dense SR ^b r.-----			1, 400	105	455	1, 050	1, 760, 000
No. 2 SR-----			1, 200	105	390	900	1, 760, 000
Dense structural 86 ^b r.-----	5 inches thick and up.		^p 2, 400	150	455	1, 800	1, 760, 000
Dense structural 72 ^b r.-----			^p 2, 000	135	455	1, 550	1, 760, 000
Dense structural 65 ^b r.-----			^p 1, 800	120	455	1, 400	1, 760, 000
Dense structural 58 ^b r.-----			^p 1, 600	105	455	1, 300	1, 760, 000
No. 1 dense SR ^b r.-----			^p 1, 600	120	455	1, 500	1, 760, 000
No. 1 SR-----			^p 1, 400	120	390	1, 300	1, 760, 000
No. 2 dense SR ^b r.-----			^p 1, 400	105	455	1, 050	1, 760, 000
No. 2 SR-----			^p 1, 200	105	390	900	1, 760, 000

Industrial 86 KD a			2, 600	165	390	1, 950	1, 760, 000
Industrial 72 KD a			2, 200	150	390	1, 650	1, 760, 000
Industrial 65 KD a			2, 000	135	390	1, 550	1, 760, 000
Industrial 58 KD a			1, 750	120	390	1, 400	1, 760, 000
Industrial 50 KD a	1 inch, 1¼		1, 500	120	390	1, 100	1, 760, 000
Industrial 86	inches, and		2, 500	150	390	1, 900	1, 760, 000
Industrial 72	1½ inches		2, 000	135	390	1, 550	1, 760, 000
Industrial 65	thick.		1, 750	120	390	1, 350	1, 760, 000
Industrial 58			1, 500	105	390	1, 250	1, 760, 000
Industrial 50			1, 200	105	390	900	1, 760, 000
<i>Oak, red and white:</i>							
2150 f grade	J. & P.	National Hardwood Lumber Association.	2, 150	145	600	1, 550	1, 650, 000
1900 f grade	J. & P.-B. & S.		1, 900	145	600	1, 375	1, 650, 000
1700 f grade	J. & P.-B. & S.		1, 700	145	600	1, 200	1, 650, 000
1450 f grade	J. & P.-B. & S.		1, 450	120	600	1, 050	1, 650, 000
1300 f grade	B. & S.		1, 300	120	600	950	1, 650, 000
1325 c grade	P. & T.				600	1, 325	1, 650, 000
1200 c grade	P. & T.				600	1, 200	1, 650, 000
1075 c grade	P. & T.				600	1, 075	1, 650, 000
<i>Pine, Norway:</i>							
Prime structural	J. & P. ^e n	National Hemlock and Hardwood Manufac- turers' Association.	1, 200	75	360	900	1, 320, 000
Common structural	J. & P. ^e n		1, 100	75	360	775	1, 320, 000
Utility structural	J. & P. ^e n		950	75	360	650	1, 320, 000
<i>Poplar, yellow:</i>							
1500 f grade	J. & P.	National Hardwood Lumber Association.	1, 500	110	300	1, 200	1, 210, 000
1250 f grade	J. & P.-B. & S.		1, 250	110	300	950	1, 210, 000
1075 c grade	P. & T.				300	1, 075	1, 210, 000

See footnotes at end of table.

Table 176. Allowable Unit Stresses—Stress-Grade Lumber—Continued

Species and commercial grade ^a		Rules under which graded	Allowable unit stresses in pounds per square inch				
			Extreme fiber in bending (f) and tension parallel to grain (t) ^e	Horizontal shear (H)	Compression perpendicular to grain (c1)	Compression parallel to grain (c)	Modulus of elasticity (E)
<i>Redwood:</i>							
Dense structural ^b	J. & P.-B. & S. ^d	California Redwood Association.	1, 700	110	320	1, 450	1, 320, 000
Heart structural	J. & P.-B. & S. ^d		1, 300	95	320	1, 100	1, 320, 000
Dense structural ^b	P. & T. ....		.....	.....	320	1, 450	1, 320, 000
Heart structural	P. & T. ....		.....	.....	320	1, 100	1, 320, 000
<i>Spruce, eastern:</i>							
1450 f structural grade	J. & P. ^d	Northeastern Lumber Manufacturers' Association, Inc.	1, 450	110	300	1, 050	1, 320, 000
1300 f structural grade	J. & P. ^d		1, 300	95	300	975	1, 320, 000
1200 f structural grade	J. & P. ^d		1, 200	95	300	900	1, 320, 000

^a Abbreviations. (For description of classification of material, see paragraph 102-B.) J. & P.=joists and planks. B. & S.=beams and stringers. P. & T.=posts and timbers. L.F.=light framing. KD=see note q. SR=stress rated.

^b These grades meet the requirement for density.

^c In tension members the slope of grain limitations applicable to the middle portion of the length of the joist-and-plank and beam-and-stringer grades used shall apply throughout the length of the piece.

^d The allowable unit stresses for tension parallel to grain (t) and for compression parallel to grain (c) given for these joist-and-plank and beam-and-stringer grades are applicable when the following additional provisions are applied to the grades: the sum of the sizes of all knots in any 6 inches of the length of the piece shall not exceed twice the maximum permissible size of knot; two knots of maximum permissible size shall not be within the same 6 inches of length of any face.

^e Value applies to pieces used as planks.

^f Value applies to 2-inch-thick pieces of select structural grade used as joists.

^g For 2-inch-thick pieces of construction and standard grades used as joists:

H=120 when length of split is approximately equal to one-half the width of piece.

H=100 when length of split is approximately equal to the width of piece.

H=70 when length of split is approximately equal to 1½ times width of piece.

^h For 3-inch-thick pieces of select structural, construction, and standard grades used as joists:

H=120 when length of split is approximately 2¼ inches.

H=80 when length of split is approximately 4½ inches, and for 4-inch-thick pieces of select structural, construction, and standard grade used as joists:

H=120 when length of split is approximately 3 inches.

H=80 when length of split is approximately 6 inches.

ⁱ For beams and stringers and for posts and timbers:

H=120 when length of split is equal to one-half the nominal narrow face dimension.

H=100 when length of split is equal to the nominal narrow face dimension.

H=80 when length of split is equal to 1½ times the nominal narrow face dimension.

^j Pieces of less than medium grain, when included in the grade of STANDARD may be considered as having a modulus of elasticity (E) of 1,320,000.

^k For 2-inch-thick pieces of construction and standard grades used as joists:

H=100 when length of split is approximately equal to one-half the width of piece.

H=80 when length of split is approximately equal to the width of piece.

H=60 when length of split is approximately equal to 1½ times the width of piece.

^l For 3-inch-thick pieces of select structural, construction, and standard grades used as joists:

H=100 when length of split is approximately 2¼ inches.

H=70 when length of split is approximately 4½ inches, and for 4-inch-thick pieces of select structural, construction, and standard grades used as joists:

H=100 when length of split is approximately 3 inches.

H=70 when length of split is approximately 6 inches.

^m For beams and stringers and for posts and timbers:

H=100 when length of split is equal to ¾ the nominal narrow face dimension.

H=90 when length of split is equal to the nominal narrow face dimension.

H=70 when length of split is equal to 1½ times the nominal narrow face dimension.

ⁿ These grades applicable to 2-inch thickness only.

^o All stress grades under the 1956 grading rules are all-purpose grades and apply to all sizes. Pieces so graded may be cut to shorter lengths without impairment of the stress rating of the shorter pieces. Grade restrictions provided by the 1956 grading rules apply to the entire length of the piece, and each piece is suitable for use in continuous spans, over double spans, or under concentrated loads without regrading for special shear or other special stress requirements. The following variations apply to the provisions of paragraph 202-B for lumber in service under wet conditions or where the moisture content is at or above fiber saturation point, as when continuously submerged: (1) the allowable unit stresses in bending, tension parallel to grain, and horizontal shear shall be limited in all thicknesses to the stresses indicated for thicknesses of 5 inches and up; (2) the allowable unit stresses for compression parallel to grain shall be limited to the stresses indicated for thicknesses of 5 inches and up reduced by 10 percent; (3) the allowable unit stresses for compression perpendicular to grain shall be reduced one-third; and (4) the values for modulus of elasticity shall be reduced by one-eleventh.

^p These stresses apply for loading either on narrow face or on wide face, which is an exception to pars. 102-B-1 and 205-B.

^q KD=kiln dried in accordance with the provisions of pars. 219 and 220 of the 1956 grading rules.

^r Longleaf may be specified by substituting "longleaf" for "dense" in the grade name, and when so specified the same allowable stresses shall apply.

Values for lengths of split other than those given in ^a, ^b, and ⁱ are proportionate.

Values for lengths of splits other than those given in ^k, ^l, and ^m are proportionate.

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174. Dimensions and Properties

Table 177 is an abridged list of American standard dressed sizes of dimension lumber, with moments of inertia and section moduli. It is assumed that the greater dimension of cross section ($=h$) is vertical.

Table 177. *Dressed Sizes of Lumber*

Nominal size	American standard	Area of section sq in.	$I = \frac{bh^3}{12}$	$S = \frac{bh^2}{6}$
		In. ²	In. ⁴	In. ³
1 x 3-----	2 $\frac{5}{32}$ x 2 $\frac{5}{8}$	2. 05	1. 18	0. 90
1 x 4-----	2 $\frac{5}{32}$ x 3 $\frac{5}{8}$	2. 83	3. 10	1. 71
1 x 6-----	2 $\frac{5}{32}$ x 5 $\frac{5}{8}$	4. 39	11. 59	4. 12
1 x 8-----	2 $\frac{5}{32}$ x 7 $\frac{1}{2}$	5. 86	27. 47	7. 32
1 x 10-----	2 $\frac{5}{32}$ x 9 $\frac{1}{2}$	7. 42	55. 82	11. 75
1 x 12-----	2 $\frac{5}{32}$ x 11 $\frac{1}{2}$	8. 98	99. 02	17. 22
2 x 4-----	1 $\frac{5}{8}$ x 3 $\frac{5}{8}$	5. 89	6. 45	3. 56
2 x 6-----	1 $\frac{5}{8}$ x 5 $\frac{5}{8}$	9. 14	24. 10	8. 57
2 x 8-----	1 $\frac{5}{8}$ x 7 $\frac{1}{2}$	12. 19	57. 13	15. 23
2 x 10-----	1 $\frac{5}{8}$ x 9 $\frac{1}{2}$	15. 44	116. 10	24. 44
2 x 12-----	1 $\frac{5}{8}$ x 11 $\frac{1}{2}$	18. 69	205. 95	35. 82
3 x 8-----	2 $\frac{5}{8}$ x 7 $\frac{1}{2}$	19. 69	92. 29	24. 61
3 x 10-----	2 $\frac{5}{8}$ x 9 $\frac{1}{2}$	24. 94	187. 55	39. 48
3 x 12-----	2 $\frac{5}{8}$ x 11 $\frac{1}{2}$	30. 19	332. 69	57. 86
4 x 12-----	3 $\frac{5}{8}$ x 11 $\frac{1}{2}$	41. 69	459. 43	79. 90
4 x 16-----	3 $\frac{5}{8}$ x 15 $\frac{1}{2}$	56. 19	1, 124. 92	145. 15
6 x 12-----	5 $\frac{1}{2}$ x 11 $\frac{1}{2}$	63. 25	697. 07	121. 23
6 x 16-----	5 $\frac{1}{2}$ x 15 $\frac{1}{2}$	85. 25	1, 706. 78	220. 23
6 x 18-----	5 $\frac{1}{2}$ x 17 $\frac{1}{2}$	96. 25	2, 456. 38	280. 73
8 x 16-----	7 $\frac{1}{2}$ x 15 $\frac{1}{2}$	116. 25	2, 327. 42	300. 31
8 x 20-----	7 $\frac{1}{2}$ x 19 $\frac{1}{2}$	146. 25	4, 634. 30	475. 31
8 x 24-----	7 $\frac{1}{2}$ x 23 $\frac{1}{2}$	176. 25	8, 111. 17	690. 31

175. Beam Design

a. Timber beams are designed using the beam formulas in paragraph 146 and the unit stresses in paragraph 173. For beams in which flexure controls, table 178 is used.

b. If deflection is the controlling factor or is limited to $\frac{1}{360}$ span (the usual requirement where plastered ceilings occur), use the deflection formulas in paragraph 133. For the beam in the example of table 160, carrying its full load of 20,300 pounds—

$$\text{Deflection} = \frac{5 w l^4}{384 E I} = \frac{4 \times 20,300 \times (16 \times 12)^3}{384 \times 1,760,000 \times 1,540} = 0.69 \text{ inch}$$

$$\text{Allowable deflection} = \frac{12 \times 16}{360} = 0.53 \text{ inch}$$

Table 178. Timber Beams Loads

Span (ft.)	Safe loads in pounds uniformly distributed for rectangular beams per inch of width (For allowable fiber stress of 1,000 p.s.i.)										
	Nominal depth of beam (in.)										
	4	6	8	10	12	14	16	18	20	22	24
4.....	370	880	1,560	2,510	3,670	5,060	-----	-----	-----	-----	-----
6.....	240	590	1,040	1,670	2,450	3,380	-----	-----	-----	-----	-----
8.....	180	440	780	1,260	1,840	2,530	-----	-----	-----	-----	-----
10.....	150	350	630	1,000	1,470	2,020	2,670	3,400	4,220	5,140	6,140
12.....	120	290	520	840	1,220	1,690	2,220	2,840	3,520	4,280	5,110
14.....	100	250	450	720	1,050	1,450	1,900	2,430	3,020	3,660	4,380
16.....	90	220	390	630	920	1,260	1,670	2,120	2,640	3,220	3,840
18.....	80	200	350	560	820	1,120	1,480	1,890	2,340	2,860	3,400
20.....	70	180	310	500	730	1,010	1,330	1,700	2,110	2,570	3,060
22.....	-----	160	280	460	670	920	1,210	1,540	1,920	2,340	2,790
24.....	-----	150	260	420	610	840	1,110	1,420	1,760	2,140	2,560
26.....	-----	140	240	390	560	780	1,030	1,310	1,620	1,980	2,360
28.....	-----	130	220	360	530	720	950	1,210	1,510	1,830	2,190
30.....	-----	120	210	330	490	670	890	1,130	1,410	1,710	2,040
32.....	-----	110	200	310	460	630	830	1,060	1,320	1,610	1,920
34.....	-----	100	180	290	430	590	780	1,000	1,240	1,510	1,810

For fiber stresses other than 1,000 pounds per square inch, change safe loads proportionately.

Example. a. Problem. What is the safe uniformly distributed load on a beam 8 inches by 14 inches of select structural Douglas fir, inland region, on a 16-foot span?

b. Solution. From par. 173, the fiber stress is 2,150 pounds per square inch. From the table above, the safe load at 1,000 pounds per square inch is 1,260 pounds per inch of width. The actual width of an 8-inch surfaced timber is $7\frac{1}{2}$ inches. The safe load is then

$$7\frac{1}{2} \times 1,260 \frac{2,150}{1,000} = 20,300 \text{ pounds}$$

At 35 pounds per cubic foot the beam weighs about 435 pounds. This is about $2\frac{1}{2}$ percent of the total safe load and normally can be neglected.

To hold deflection to $\frac{1}{360}$ of the span for building design, the load is reduced to $\frac{5}{9}$ of 20,300 or 15,600 pounds, or a deeper beam is selected.

c. Horizontal shear is likely to be the controlling factor in the safe loads for relatively short beams loaded to full flexural strength; it rarely affects the design of longer beams. Safe loads are given in table 179.

Table 179. Safe Loads for Short Beams

Safe loads in pounds uniformly distributed for rectangular beams, per inch of width (For allowable horizontal shear of 100 pounds per square inch)					
Depth (inches)	Safe load (pounds)	Depth (inches)	Safe load (pounds)	Depth (inches)	Safe load (pounds)
4	480	12	1, 530	20	2, 600
6	750	14	1, 800	22	2, 870
8	1, 000	16	2, 060	24	3, 130
10	1, 260	18	2, 330		

For allowable stresses other than 100 pounds per square inch, change safe loads proportionately.

Example. Assume the 8-inch by 14-inch beam in the example in table 160 is used on a 10-foot span. The allowable load due to flexure is—

$$7\frac{1}{2} \times 2,020 \times \frac{2,150}{1,000} = 32,600 \text{ pounds}$$

Allowable load due to horizontal shear (stress is given as 145 pounds per square inch in paragraph 161):

$$7\frac{1}{2} \times 1,800 \times \frac{145}{100} = 19,600 \text{ pounds}$$

In this case the shear controls the allowable load.

176. Column Design

a. The safe axial load for a wood column of square or rectangular cross section is given by the formula—

$$P = A \frac{0.30E}{(l/d)^2}$$

Where P = safe load in pounds

A = cross-sectional area in square inches

E = modulus of elasticity in psi

l = length (height) of column, in inches

d = dimension of the least side of the cross section, in inches.

(It is to be noted that, for dressed lumber, this is the actual dimension, not the nominal.)

In this formula, P/A must not exceed c , the allowable unit stress in compression, parallel to grain, for the wood in question.

Table 180. Safe Loads—Dressed-Lumber Columns

Nominal dimensions of cross section (inches)	Length (feet)	Safe load (kips)
4 by 4.....	6	17.5
	8	9.9
	10	6.3
4 by 6.....	8	15.3
	10	9.8
	12	6.8
6 by 6.....	8	52.1
	10	33.6
	12	23.3
6 by 8.....	10	45.8
	12	31.7
	14	23.4
	16	17.9
8 by 8.....	10	116.0
	12	80.5
	14	59.2
	16	45.3
8 by 10.....	10	147.0
	12	102.0
	14	75.0
	16	57.4
	18	45.4
10 by 10.....	10	300.1
	12	206.3
	14	152.1
	16	116.8
	18	92.5
8 by 12.....	10	178.0
	12	123.5
	14	90.7
	16	69.5
	18	55.0
10 by 20.....	12	249.7
	14	184.1
	16	141.4
	18	112.0
	20	90.1
12 by 12.....	12	446.7
	14	327.6
	16	250.3
	18	197.6
	20	159.9

b. Some representative values of safe loads in dressed-lumber columns are given in table 180, based on $E=1,760,000$, the accepted value for southern pine and coastal Douglas fir.

177. Connections in Wood Framing

In wood trusses and similar structures, sizes of members may be controlled by the thickness and width necessary for the design of connections which will transmit the stresses. Working loads for various fastenings are as follows: -

a. *Nails and Spikes.* The safe lateral load for one nail or spike driven into the side grain of seasoned lumber so that at least two-thirds of the length of the nail is in the wood member holding the point (reduce load 60 percent for nails in end grain and 25 percent for unseasoned wood) is as follows:

$900 \times D^{3/2}$ for white pine and eastern hemlock

$1200 \times D^{3/2}$ for Douglas fir and southern yellow pine

$1700 \times D^{3/2}$ for oak, ash, and hard maple

Where D =diameter of nail, in inches.

Table 181 shows various nail and spike sizes.

Table 181. Nail and Spike Sizes

	Size	Length (inches)	Gage	Diameter (D) (inches)	$D^{3/2}$
Nails-----	3d	1¼"	14	0.0800	0.0226
	4d	1½"	12½	.0985	.0309
	6d	2"	11½	.1130	.0380
	8d	2½"	10¼	.1314	.0476
	10d	3"	9	.1483	.0570
	16d	3½"	8	.1620	.0652
	20d	4"	6	.1920	.0841
	30d	4½"	5	.2070	.0942
	40d	5"	4	.2253	.1066
	60d	6"	2	.2625	.1347
Spikes-----	7"	7"	5/16"	5/16"	0.1750
	8"	8"	3/8"	3/8"	.2295
	9"	9"	3/8"	3/8"	.2295
	10"	10"	3/8"	3/8"	.2295
	12"	12"	3/8"	3/8"	.2295

b. *Wood Screws.* The safe lateral load for one wood screw driven into the side grain of seasoned lumber to a penetration of at least seven times its diameter into the member receiving the point (reduce load 25 percent for end grain and 25 percent for unseasoned wood) is as follows:

$2100 \times D^2$ for white pine and eastern hemlock

$2700 \times D^2$ for Douglas fir and southern yellow pine

$4000 \times D^2$ for oak, ash, and hard maple

Table 182. Wood Screw Diameters

Size	Diameter-D	D ²
	<i>Inches</i>	<i>Inches²</i>
½ inch—No. 4.....	0. 1105	0. 0122
¾ inch—No. 8.....	. 1631	. 0266
1 inch—No. 10.....	. 1894	. 0359
1½ inch—No. 12.....	. 2158	. 0466
2 inch—No. 14.....	. 2421	. 0586
2½ inch—No. 16.....	. 2684	. 0720
3 inch—No. 18.....	. 2947	. 0868

Where D=diameter of shank of screw, in inches.

Typical wood-screw diameters are shown in table 182.

c. Lag Screws.

- (1) The safe lateral load for one lag screw driven into the side grain of seasoned lumber to a penetration of nine times the diameter into the member receiving the point and holding a cleat having a thickness of 3.5 times the screw diameter (reduce load 35 percent for end grain and 25 percent for unseasoned wood) is as follows:

1500×D² for white pine and eastern hemlock

1700×D² for Douglas fir and southern cypress

1900×D² for southern yellow pine and soft maple

2200×D² for oak, ash, and hard maple

Where D=diameter of shank, in inches.

- (2) If the cleat thickness is more or less than 3½ times the screw diameter, use percentages of safe loads as shown in figure 84.
- (3) If the penetration of the lag screw into the member receiving the point is more than nine times the screw diameter; that is, if the unthreaded shank penetrates the members, the load may be increased by the percentages in figure 85, up to an increase of 39 percent for a penetration of 7 or more diameters of the shank.

d. Bolts.

- (1) *Basic stresses.* The basic allowable working stresses for the design of bolted joints in various species are shown in table 183.

- (2) *Stress reductions.* The above basic stresses apply to the bearing area (bolt diameter times length of contact area) of a member in double shear; that is, a main tension member with metal splice plates on both faces or wood splice plates one-half the thickness of the main member, except that for tension member with wood splice plates the stress used is reduced by 20 percent. The basic stresses apply to seasoned

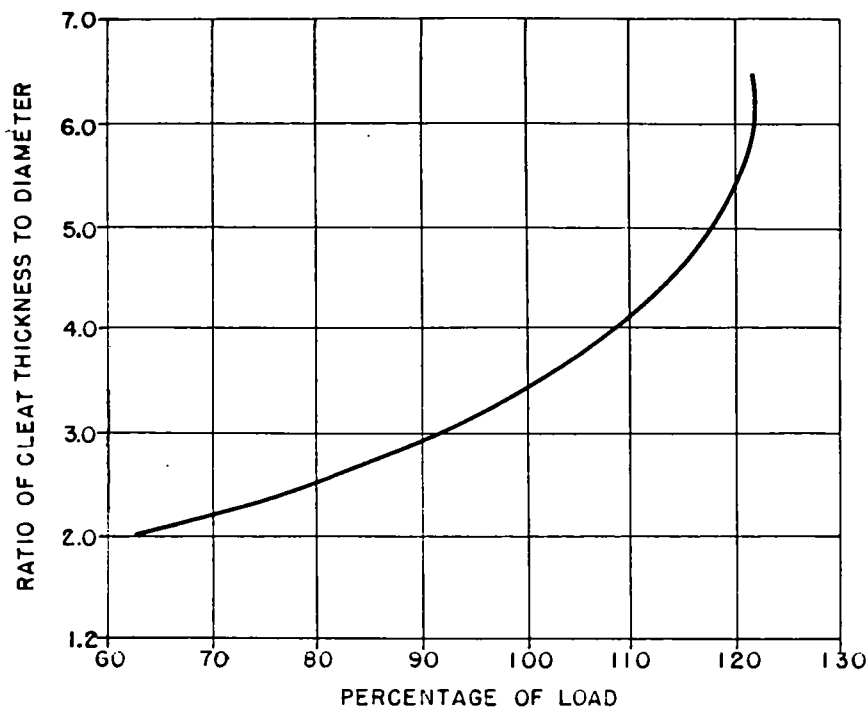


Figure 84. Lag screws: percentage of full load for various cleat thicknesses.

Table 183. Stresses in Bolted Joints

Species group No.	Species	Basic stress, p. s. i.	
		Parallel with grain	Perpendicular to grain
1	White fir, eastern hemlock, white pine, spruce--	960	180
2	Red cedar, western hemlock, Norway pine-----	1, 200	240
3	Douglas fir, redwood, southern yellow pine----	1, 560	280
4	Aspen, basswood, poplar-----	1, 110	210
5	Elm, gum, soft maple-----	1, 440	300
6	White ash, beech, birch, maple, oak, walnut---	1, 800	480

lumber, dry conditions, proper bolt spacing, and low L/D ratio (length of bolt contact÷bolt diameter). Reductions for various conditions are made as follows:

- (a) *Bolt diameter.* For loads perpendicular to the grain, the basic stresses are increased by the factors shown in table 184.
- (b) *L/D ratio; stress parallel with grain.* For loads parallel with the grain and for L/D ratios more than 2, the basic stresses are shown in figure 86 for the six groups of species.

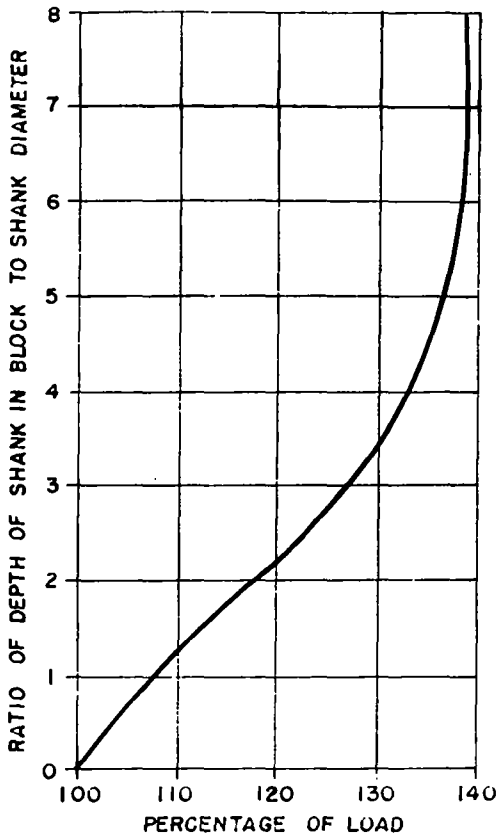


Figure 85. Lag screws: percentage of full load for penetration in excess of nine diameters.

- (c) *L/D ratio; stress perpendicular to grain.* For loads perpendicular to the grain, the stresses are reduced as shown in figure 87.
- (d) *Exposure and seasoning.* For joints exposed to the weather, use 75 percent of values otherwise obtained; 67 percent if usually wet or damp; and 33 percent for green lumber allowed to season under load.
- (3) *Example.* A main tension member 4 inches thick (actually $3\frac{5}{8}$) of seasoned Douglas fir for use indoors, connected by four $\frac{3}{4}$ -inch bolts through wood splice plates. Bearing area, 3.625×0.75 , is 2.72 square inches *L/D* ratio, $3.625 \div 0.75$, is 4.83, for which (2)(b) above gives a unit stress of 1370 for group 3. Reducing 20 percent for wood splice plates brings this to 1095 pounds per square inch. The allowable load is $1095 \times 2.72 \times 4$, or about 11,900 pounds.

Table 184. Bolt Diameter Stress Factors

Bolt diameter (inches)	Diameter factor	Bolt diameter (inches)	Diameter factor
1/4-----	2.50	1 1/4-----	1.19
3/8-----	1.95	1 1/2-----	1.14
1/2-----	1.68	1 3/4-----	1.10
5/8-----	1.52	2-----	1.07
3/4-----	1.41	2 1/2-----	1.03
7/8-----	1.33	3 and over-----	1
1-----	1.27		

e. Timber Connectors.

- (1) *Types available.* The types of timber connectors which are standard items of issue include the 2½- and 4-inch split ring and the 4-inch toothed ring. The design data below cover the split-ring connector, which is the type regularly used. It is installed quickly and accurately in a groove made by a cutter in a ¾-inch electric drill, whereas the toothed ring is embedded by drawing the timbers together with a high-strength bolt with smooth thread and a ball-bearing washer, to be then replaced by the regular bolt. The 4-inch toothed-ring connector has design values about 10 percent below those of the 4-inch split ring. It is used in comparatively light construction or in isolated locations where a heavy-duty drill is not available. Bolt diameters are ½ inch for 2½-inch rings, ¾ inch for 4-inch rings. Plate washer sizes are 2 by 2 by ⅛ inch and 3 by 3 by ⅜ inch for 2½- and 4-inch rings, respectively.

- (2) *Species groups.* The connector load groupings for various species of lumber of structural grades are as follows:

Connector load group	Species
A-----	Dense Douglas fir, oak, and longleaf yellow pine.
B-----	Coastal Douglas fir, larch, and shortleaf yellow pine.
C-----	Cypress, western hemlock, Norway pine, and redwood.

- (3) *Edge and end distances.* Minimum distances from center of connector to edges and end of members are shown in figures 88, 89, 90, and 91.

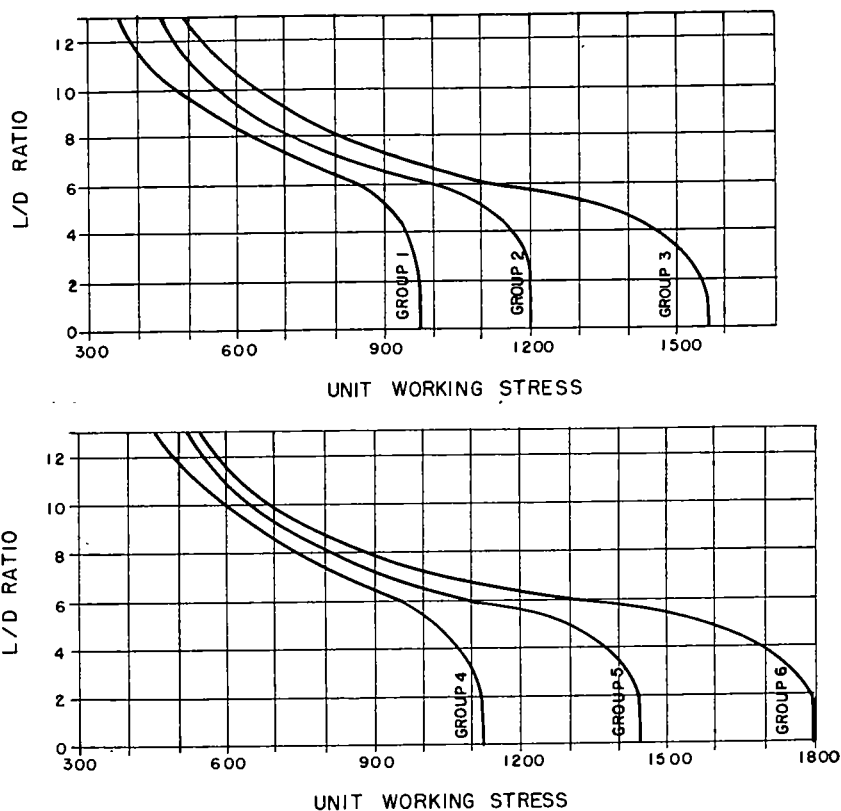


Figure 86. Bolted joints: unit working stresses for loads parallel with grain.

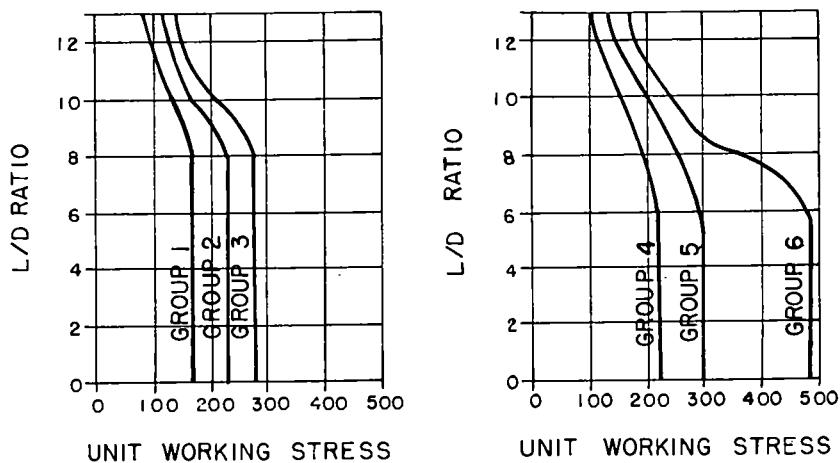


Figure 87. Bolted joints: unit working stresses for loads perpendicular to grain.

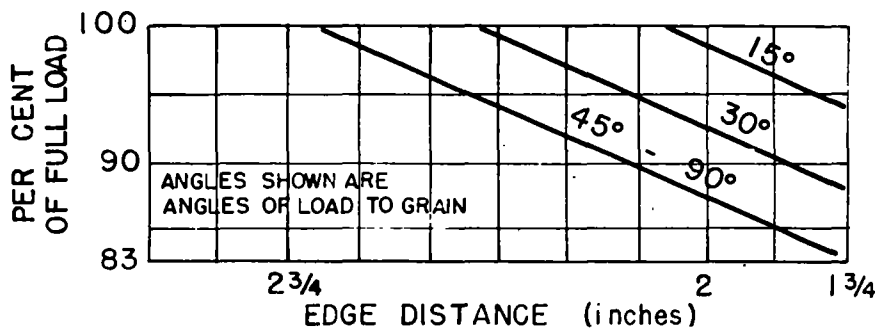


Figure 88. Edge distance for 2½-inch split rings.

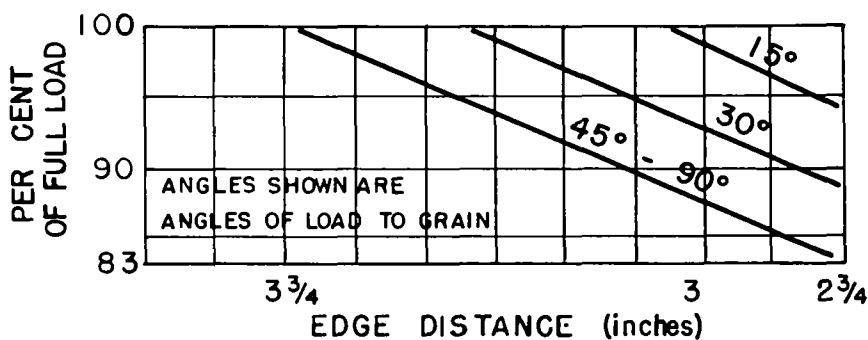


Figure 89. Edge distance for 4-inch split rings.

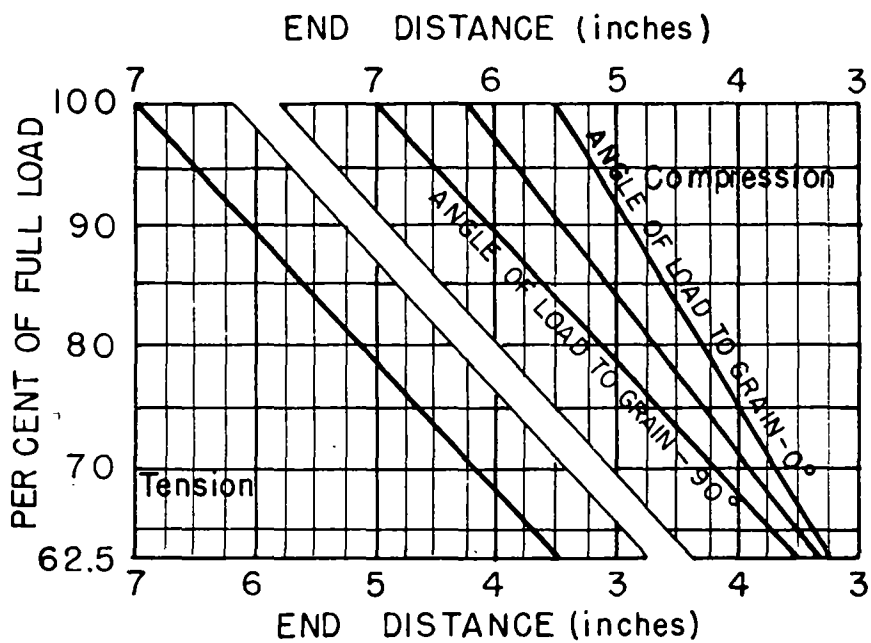


Figure 90. End distance for 2½-inch split rings.

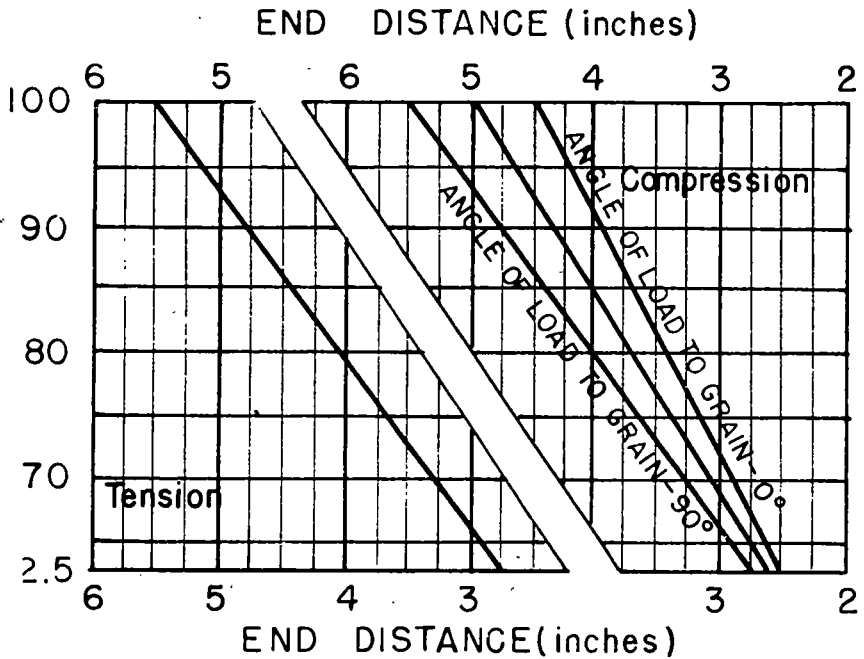


Figure 91. End distance for 4-inch split rings.

(4) *Spacing.*

- (a) For 2½-inch rings, 3½-inch spacing is minimum and permits applying 75 percent of the full loads given below. For full load and various angles of load to grain, spacings vary from 4¼ inches perpendicular to grain for loads at 60° to 90° with the grain, to 6¼ inches parallel with the grain for loads parallel with the grain.
- (b) For 4-inch rings, the above values are: 5-inch spacing for 75 percent loading varying to 6-inch spacing perpendicular to grain and 9-inch spacing parallel with grain for loads parallel with the grain.
- (5) *Allowable loads.* For satisfactory distances and spacing, and for long-term or permanent loading, safe loads per connection are shown in figures 92 and 93. The values may be increased 15 percent for loads applied for periods of not over 3 months or for snow loads, 50 percent for 0 wind or earthquake loads, or 100 percent for impact loads.

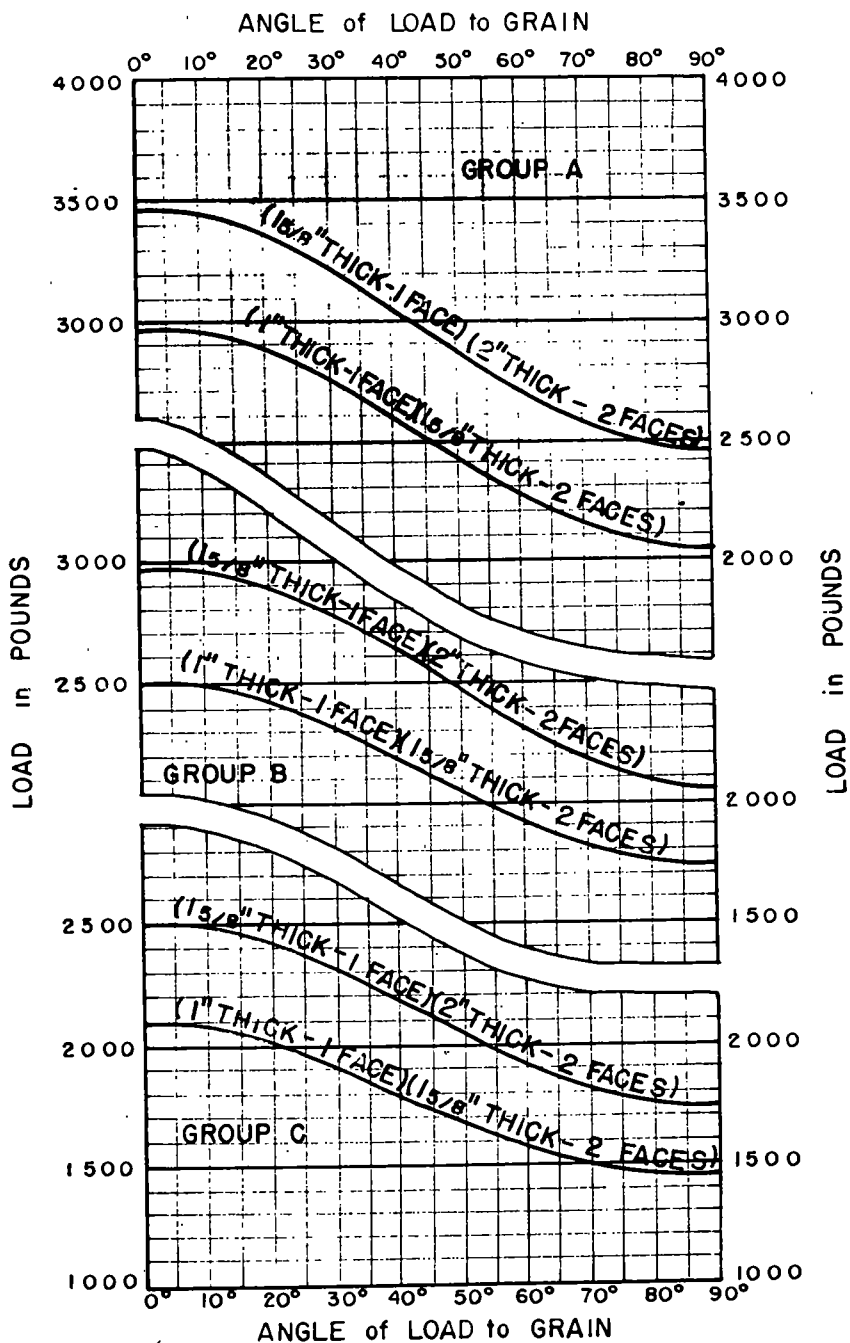


Figure 92. Safe loads for one 2½-inch ring and bolt in single shear.

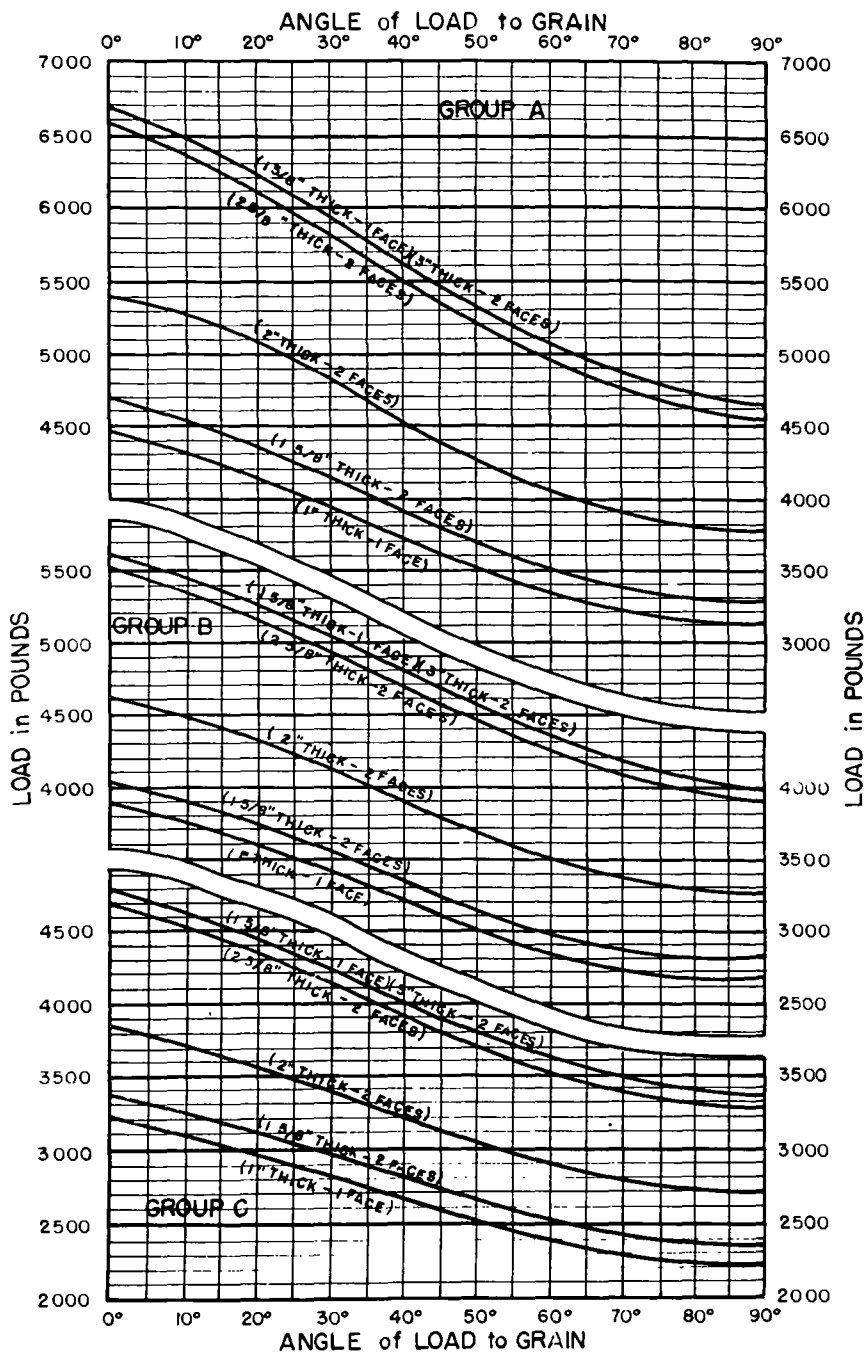


Figure 93. Safe loads for one 4-inch ring and bolt in single shear.

CHAPTER 10

MATERIALS OF CONSTRUCTION

Section I. WOOD

178. Board Measure

a. Lumber quantities are expressed in feet, board measure (ft. b.m.) or in board feet (bd. ft.), or in thousand board feet (M bd. ft.). One board foot (or ft. b.m.) is the amount of lumber in a rough-sawed board 1 foot long, 1 foot wide, and 1 inch thick (144 cubic inches) or the equivalent volume in any other shape. These original or "nominal" dimensions and volumes determine the number of board feet in a given quantity of dressed lumber, regardless of the fact that the process of surfacing or other machining has reduced the actual dimensions and volume. Under American standards, for example, a dressed board designated as 1 inch by 12 inches is in fact $2\frac{1}{2}$ inch by $11\frac{1}{2}$ inches. This must be taken into account in computing the amount of lumber needed for a given job. Thus, one hundred 1-inch by 12-inch dressed boards 16 feet long contain $\frac{100 \times 1 \times 12 \times 16}{12} = 1,600$ board feet, but have an actual area of only $\frac{100 \times 11\frac{1}{2} \times 16}{12} = 1,533$ square feet; so that if 1,600 square feet of 1-inch by 12-inch material are desired, 1,670 board feet, plus allowance for wastage, must be ordered.

b. Table 185 gives the number of board feet in one piece of lumber of the sizes given.

179. International Log Rule

A log rule, or scale, is marked at each inch with the number of board feet which can be sawed from logs if the log is measured inside the bark at the small end. Many such rules have been devised, recognized in the lumber industry, and used in various localities. The international $\frac{1}{4}$ -inch log rule, which is based on $\frac{1}{4}$ -inch saw kerfs, has been adopted by statute in some states and may eventually become the universal standard. In applying the rule, no interpolation is made for diameters between inch marks, but scaling practice in some localities permits using the next higher inch for diameters with a fraction larger than $\frac{1}{2}$ inch; for example, a log $23\frac{3}{4}$ inches in diameter is scaled as 24 inches. The scale is given in table 186.

Table 185. Board Feet

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
2 by 4.....	6 $\frac{2}{3}$	8	9 $\frac{1}{3}$	10 $\frac{2}{3}$	12	13 $\frac{1}{3}$	14 $\frac{2}{3}$	16
2 by 6.....	10	12	14	16	18	20	22	24
2 by 8.....	13 $\frac{1}{3}$	16	18 $\frac{2}{3}$	21 $\frac{1}{3}$	24	26 $\frac{2}{3}$	29 $\frac{1}{3}$	32
2 by 10.....	16 $\frac{2}{3}$	20	23 $\frac{1}{3}$	26 $\frac{2}{3}$	30	33 $\frac{1}{3}$	36 $\frac{2}{3}$	40
2 by 12.....	20	24	28	32	36	40	44	48
2 by 14.....	23 $\frac{1}{3}$	28	32 $\frac{2}{3}$	37 $\frac{1}{3}$	42	46 $\frac{2}{3}$	51 $\frac{1}{3}$	56
2 by 16.....	26 $\frac{2}{3}$	32	37 $\frac{1}{3}$	42 $\frac{2}{3}$	48	53 $\frac{1}{3}$	58 $\frac{2}{3}$	64
3 by 6.....	15	18	21	24	27	30	33	36
3 by 8.....	20	24	28	32	36	40	44	48
3 by 10.....	25	30	35	40	45	50	55	60
3 by 12.....	30	36	42	48	54	60	66	72
3 by 14.....	35	42	49	56	63	70	77	84
3 by 16.....	40	48	56	64	72	80	88	96
4 by 4.....	13 $\frac{1}{3}$	16	18 $\frac{2}{3}$	21 $\frac{1}{3}$	24	26 $\frac{2}{3}$	29 $\frac{1}{3}$	32
4 by 6.....	20	24	28	32	36	40	44	48
4 by 8.....	26 $\frac{2}{3}$	32	37 $\frac{1}{3}$	42 $\frac{2}{3}$	48	53 $\frac{1}{3}$	58 $\frac{2}{3}$	64
4 by 10.....	33 $\frac{1}{3}$	40	46 $\frac{2}{3}$	53 $\frac{1}{3}$	60	66 $\frac{2}{3}$	73 $\frac{1}{3}$	80
4 by 12.....	40	48	56	64	72	80	88	96
4 by 14.....	46 $\frac{2}{3}$	56	65 $\frac{1}{3}$	74 $\frac{2}{3}$	84	93 $\frac{1}{3}$	102 $\frac{2}{3}$	112
4 by 16.....	53 $\frac{1}{3}$	64	74 $\frac{2}{3}$	85 $\frac{1}{3}$	96	106 $\frac{2}{3}$	117 $\frac{1}{3}$	128
6 by 6.....	30	36	42	48	54	60	66	72
6 by 8.....	40	48	56	64	72	80	88	96
6 by 10.....	50	60	70	80	90	100	110	120
6 by 12.....	60	72	84	96	108	120	132	144
6 by 14.....	70	84	98	112	126	140	154	168
6 by 16.....	80	96	112	128	144	160	176	192
6 by 18.....	90	108	126	144	162	180	198	216
6 by 20.....	100	120	140	160	180	200	220	240
8 by 8.....	53 $\frac{1}{3}$	64	74 $\frac{2}{3}$	85 $\frac{1}{3}$	96	106 $\frac{2}{3}$	117 $\frac{1}{3}$	128
8 by 10.....	66 $\frac{2}{3}$	80	93 $\frac{1}{3}$	106 $\frac{2}{3}$	120	133 $\frac{1}{3}$	146 $\frac{2}{3}$	160
8 by 12.....	80	96	112	128	144	160	176	192
8 by 14.....	13 $\frac{1}{3}$	112	130 $\frac{2}{3}$	149 $\frac{1}{3}$	168	186 $\frac{2}{3}$	205 $\frac{1}{3}$	224
10 by 10.....	83 $\frac{1}{3}$	100	116 $\frac{2}{3}$	133 $\frac{1}{3}$	150	166 $\frac{2}{3}$	183 $\frac{1}{3}$	200
10 by 12.....	100	120	140	160	180	200	220	240
10 by 14.....	116 $\frac{2}{3}$	140	163 $\frac{1}{3}$	186 $\frac{2}{3}$	210	233 $\frac{1}{3}$	256 $\frac{2}{3}$	280
10 by 16.....	133 $\frac{1}{3}$	160	186 $\frac{2}{3}$	213 $\frac{1}{3}$	240	266 $\frac{2}{3}$	293 $\frac{1}{3}$	320
12 by 12.....	120	144	168	192	216	240	264	288
12 by 14.....	140	168	196	224	252	280	308	336
12 by 16.....	160	192	224	256	288	320	352	384
14 by 14.....	163 $\frac{1}{3}$	196	228 $\frac{2}{3}$	261 $\frac{1}{3}$	294	326 $\frac{2}{3}$	359 $\frac{1}{3}$	392
14 by 16.....	186 $\frac{2}{3}$	224	261 $\frac{1}{3}$	298 $\frac{2}{3}$	336	373 $\frac{1}{3}$	410 $\frac{2}{3}$	448

Table 186. Log Scale

Diameter (inches)	Length of log in feet (board measure)						
	8	10	12	14	16	18	20
6-----	10	10	15	15	20	25	25
7-----	10	15	25	30	30	35	40
8-----	15	20	25	35	40	45	50
9-----	20	30	35	45	50	60	70
10-----	30	35	45	55	65	75	85
11-----	35	45	55	70	80	95	105
12-----	45	55	70	85	95	110	125
13-----	55	70	85	100	115	135	150
14-----	65	80	100	115	135	155	175
15-----	75	95	115	135	160	180	205
16-----	85	110	130	155	180	205	235
17-----	95	125	150	180	205	235	265
18-----	110	140	170	200	230	265	300
19-----	125	155	190	225	260	300	335
20-----	135	175	210	250	290	330	370
21-----	155	195	235	280	320	365	410
22-----	170	215	260	305	355	405	455
23-----	185	235	285	335	390	445	495
24-----	205	255	310	370	425	485	545
25-----	220	280	340	400	460	525	590
26-----	240	305	370	435	500	570	640
27-----	260	330	400	470	540	615	690
28-----	280	355	430	510	585	665	745
29-----	305	385	465	545	630	715	800
30-----	325	410	495	585	675	765	860
31-----	350	440	530	625	720	820	915
32-----	375	470	570	670	770	875	980
33-----	400	500	605	715	820	930	1045
34-----	425	535	645	760	875	990	1110
35-----	450	565	685	805	925	1050	1175
36-----	475	600	725	855	980	1115	1245
37-----	505	635	770	905	1040	1175	1315
38-----	535	670	810	955	1095	1245	1390
39-----	565	710	855	1005	1155	1310	1465
40-----	595	750	900	1060	1220	1380	1540
41-----	625	785	950	1115	1280	1450	1620
42-----	655	825	995	1170	1345	1525	1705
43-----	690	870	1045	1230	1410	1600	1785
44-----	725	910	1095	1290	1480	1675	1870
45-----	755	955	1150	1350	1550	1755	1960
46-----	795	995	1200	1410	1620	1835	2050
47-----	830	1040	1255	1475	1695	1915	2140
48-----	865	1090	1310	1540	1770	2000	2235

Section II. STEEL PRODUCTS

180. Corrugated Sheet Metal

a. Black sheet iron with 2½-inch corrugations is stocked in oversca depots as a class IV item, in two sizes as follows:

<i>United States standard gage</i>	<i>Thickness (inches)</i>	<i>Pounds per square foot ¹</i>	<i>Width (inches)</i>	<i>Length (feet)</i>
28.....	0. 015	0. 68	27	8
22.....	. 030	1. 36	27	11

¹ Based on sheets 27 inches wide, lapped 3 inches.

b. Technical data on black and galvanized sheet metal with 2½-inch corrugations are given in table 187.

181. Wire Rope.

a. General. Wire rope is manufactured from six types of metal and in many combinations of wire size, number of wires per strand, number of strands, and core types. Standard hoisting rope is made of 6 strands of 19 wires each, over a hemp core. It is flexible enough to operate over sheaves of practicable sizes. Using smaller wire sizes, ropes of 6 strands of 37 wires and of 8 strands of 19 wires are more flexible and permit smaller sheave sizes. Using larger wires, ropes of 6 strands of 7 wires are suitable for standing rope service, such as guys and moorings. They require much larger sheaves if used over sheaves.

b. Sheave Sizes. Standard hoisting rope, 6 strands of 19 wires, requires a sheave diameter of 45 times the rope diameter to avoid excessive deterioration from bending stresses, and an absolute minimum sheave diameter of 30 times the rope diameter. Recommended

Table 187. *Black and Galvanized Sheet Metal—2½-inch Corrugations*

U.S. Standard gage	Thickness (inches)	Pounds per square foot ¹		Maximum span (feet)	
		Galvanized	Black	Roofing	Siding
28.....	0. 015	0. 85	0. 68	2' 9"	3' 10"
26.....	. 018	. 99	. 82	2' 9"	3' 10"
24.....	. 024	1. 26	1. 09	3' 9"	4' 10"
22.....	. 030	1. 53	1. 36	4' 9"	5' 10"
20.....	. 036	1. 81	1. 64	5' 9"	5' 10"
18.....	. 048	2. 35	2. 18	5' 9"	5' 10"
16.....	. 060	2. 90	2. 73	5' 9"	5' 10"
14.....	. 075	3. 58	3. 41	5' 9"	5' 10"
12.....	. 105	4. 94	4. 77	5' 9"	5' 10"

¹ Based on sheets 27 inches wide, lapped 3 inches.

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and minimum sheave diameters for standard and other wire ropes are given in table 188.

Table 188. Sheave Diameters for Wire Rope

Type of wire rope (strands by wires)	Recommended sheave or drum diameter	Minimum sheave or drum diameter
6 by 7-----	72 × rope diameter-----	42 × rope diameter.
6 by 19-----	45 × rope diameter-----	30 × rope diameter.
6 by 37-----	27 × rope diameter-----	18 × rope diameter.
8 by 19-----	31 × rope diameter-----	21 × rope diameter.

c. *Breaking Strength.* While the breaking strength of wire rope varies slightly with the strand construction and number of strands, it depends primarily upon the type of metal used. The breaking strength of standard 6 by 19 hoisting rope, given in table 189 for each type of metal, is about 10 percent higher than that of 6 by 7 standing rope and slightly lower than that of some of the more flexible wire ropes.

d. *Safety Factors.* The minimum safety factors for new wire rope in various types of service are given in table 190. These factors are increased for high-speed operation, impact, inadequate sheave diameters, for old or worn rope, or if the results of a failure would be exceptionally serious.

182. Wire Rope Requirements for Engineer Equipment

Table 191 gives wire rope requirements for selected engineer equipment.

Table 189. Breaking Strength of Wire Rope

Breaking strength in tons (6 by 19 wire rope)									
Diameter (inches)	3⁄8	1⁄2	5⁄8	3⁄4	7⁄8	1	1 1⁄8	1 1⁄4	1 1⁄2
Approximate weight per hundred feet (pounds)-----	23	40	63	90	123	160	203	250	360
Material									
Wrought iron-----	2.1	3.6	5.5	7.9	10.6	13.7	17.2	21.0	29.7
Traction steel-----	4.0	6.8	10.4	14.8	20.0	26.0	32.7	40.6	56.6
Cast steel-----	4.5	7.7	11.8	16.8	22.8	29.5	37.0	46.0	65.0
Mild plow steel-----	5.0	8.5	13.1	18.7	25.4	33.0	41.5	51.0	72.5
Plow steel-----	5.5	9.4	14.4	20.6	28.0	36.5	46.0	56.5	80.5
Improved plow steel-----	6.3	10.8	16.6	23.7	32.2	42.0	53.0	65.0	92.5

Table 190. Wire Rope Minimum Safety Factors

Type of service	Minimum safety factor
Track cables.....	3.2
Guys.....	3.5
Cable tools operating at depths in feet as shown:	
0 to 500.....	8.0
500 to 1000.....	7.0
1000 to 2000.....	6.0
2000 to 3000.....	5.0
3000 and over.....	4.0
Miscellaneous hoisting equipment.....	5.0
Haulage ropes.....	6.0
Derricks.....	6.0
Slings.....	8.0

183. Wire-Rope Accessories

a. *Types.* Clips (U-bolts and saddles) and thimbles are shown in figure 94; spliced loops and various types of sockets in figure 95.

b. *Efficiency.* Based on careful makeup, connection strengths are given in table 192 in percentages of the breaking strength of new wire rope. Basket sockets should be made up with zinc at 830° F., but the strength when made up with lead or babbitt metal is given for reference in case such sockets are found in use. The figures given are the maximum allowable and can be counted on only under ideal conditions.

184. Chains and Hooks

a. *Chains.* For typical straight-link chain, the safe load in tons is approximately eight times the square of the diameter in inches of the rod used to make the chain. If the type of metal used in the chain is known, safe loads are given more accurately by table 193.

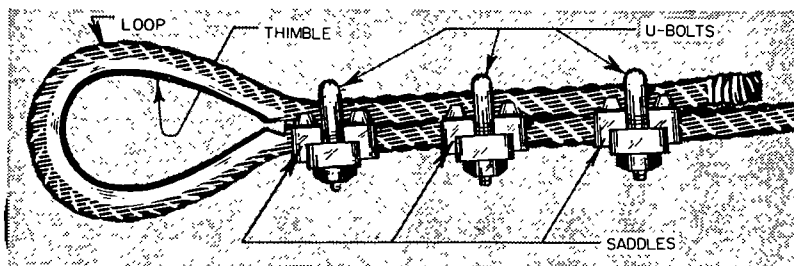


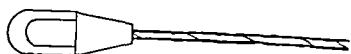
Figure 94. Wire-rope clips and thimbles.



LOOP



LOOP WITH THIMBLE



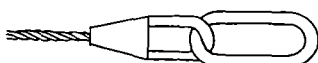
CLOSED SOCKET



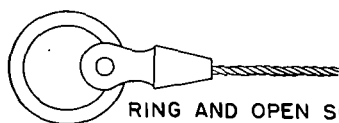
OPEN SOCKET



LINK AND THIMBLE



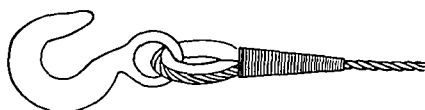
LINK AND CLOSED SOCKET



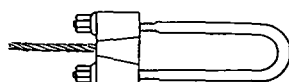
RING AND OPEN SOCKET



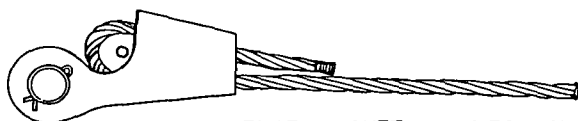
THIMBLE AND SHACKLE



HOOK AND THIMBLE



BRIDGE SOCKET



WEDGE-SOCKET CONNECTION

Figure 95. Wire-rope fittings.

Table 191. Wire Rope Requirements for Engineer Equipment

Item of equipment	Attachment and application	Length (feet)	Diameter (inches)
Crane, revolving, tractor mounted, 6,000-lb capacity at 12-ft. radius; FSN 3830-240-7647.	Erection.....	25.....	1/2
	Boom suspension cable.....	96.....	1/2
	Crane hoist cable.....	3 times boom length plus 15 ft..	1/2
	Dragline hoist cable.....	Twice boom length plus 15 ft.....	3/8
	Dragline drag cable.....	Boom length plus 25 ft.....	3/8
	Dragline dump cable.....	13.....	3/8
	Clamshell holding cable.....	Twice boom length plus 15 ft.....	1/2
	Clamshell closing cable.....	Twice boom length plus 45 ft.....	1/2
	Tagline.....	45.....	3/16
	Shovel hoist cable.....	90.....	3/8
	Shovel crowd cable.....	60.....	3/8
	Dipper trip line.....	36.....	1/4
	Back hoe hoist cable.....	65.....	1/2
	Back hoe drag cable.....	65.....	3/8
	Back hoe dipper cable.....	45.....	3/8
Crane shovel, basic unit, crawler mounted, 10 tons, 30-ft. boom at 12-ft. radius; MII-C-15467; FSN 3810-188-7060.	Clamshell holding line.....	108.....	3/8
	Clamshell closing line.....	120.....	3/8
	Shovel hoist line.....	80.....	3/8
	Shovel trip line.....	42.....	3/16
	Shovel boom line.....	118.....	1/2
	Pull shovel hoist line.....	105.....	3/8
	Pull shovel pull-in line.....	60.....	3/4
	Pull shovel bail line.....	80.....	1 1/2
	Crane boom line.....	326.....	1/2
	Dragline.....	64.....	3/4
	2-part hoist line.....	156.....	3/8

Crane shovel, crawler mounted, 40 ton, 50-ft. boom
at 12-ft. radius, 2 cu. yd.; MIL-C-15467; FSN
3810-230-3819.

Crane shovel power unit, revolving, truck mounted
12½ ton; MIL-C-10466; FSN 3810-264-4842.

Clamshell holding line.....	150.....	¾
Clamshell closing line.....	185.....	¾
Tagline.....	85.....	¾
Shovel hoist line.....	95.....	1
Shovel trip line.....	35.....	⅝
Shovel boom line.....	145.....	¾
Pull shovel hoist line.....	125.....	1
Pull shovel pull-in line.....	43.....	1¼
Crane boom line.....	325.....	1
Dragline.....	180.....	1
2-part hoist line.....	205.....	1
Crane:		
Boom hoist.....	118.....	⅝
Boom stop.....	15' 2".....	½
Hoist:		
Single line:		
30-ft boom.....	80.....	½
35-ft boom.....	90.....	½
40-ft boom.....	100.....	½
Three-part line:		
30-ft boom.....	150.....	½
35-ft boom.....	170.....	½
40-ft boom.....	190.....	½
Four-part line:		
30-ft boom.....	185.....	½
35-ft boom.....	210.....	½
40-ft boom.....	235.....	½
Clamshell:		
Holding:		
30-ft boom.....	65.....	½
35-ft boom.....	76.....	½
40-ft boom.....	85.....	½

Table 191. Wire Rope Requirements for Engineer Equipment—Continued

Item of equipment	Attachment and application	Length (feet)	Diameter (inches)
Ditching machine, crawler mounted, gas-engine driven; MIL-D-633; FSN 3805-221-1716.	Closing:		
	30-ft boom.....	90.....	$\frac{1}{2}$
	40-ft boom.....	110.....	$\frac{1}{2}$
	Tagline.....	60.....	$\frac{3}{8}$
	Dragline:		
	Hoist:		
	30-ft boom.....	85.....	$\frac{1}{2}$
	35-ft boom.....	95.....	$\frac{1}{2}$
	40-ft boom.....	105.....	$\frac{1}{2}$
	Drag:		
	30-ft boom.....	40.....	$\frac{5}{8}$
	35-ft boom.....	45.....	$\frac{5}{8}$
	40-ft boom.....	50.....	$\frac{5}{8}$
	Dump.....	20.....	$\frac{5}{8}$
	.....	82.....	$\frac{1}{2}$
Mixer, concrete, trailer mounted, gas-engine driven, 6 cu. ft. capacity; JAN-M-686; FSN 3895-238-5089.	Skip cable.....	24.....	$\frac{5}{16}$
	Hoist cable.....	34.....	$\frac{5}{16}$
Mixer, concrete, trailer mounted, 16 cu. ft. capacity; JAN-M-686; FSN 3895-238-5097.	Skip cable.....	24.....	$\frac{5}{16}$
	Hoist cable.....	34.....	$\frac{5}{16}$
Paver, concrete, crawler mounted, gas-engine driven, dual drum, 34 cu. ft. per batch capacity; MIL-M-3362; FSN 3895-239-8649.	Bucket wire rope, short.....	52' 6".....	$\frac{3}{8}$
	Bucket wire rope, long.....	84.....	$\frac{3}{8}$
	Boom support cable.....	130.....	$\frac{5}{8}$
	Skip hoist cable.....	56' 6".....	$\frac{3}{4}$

Rooter, road, towed, cable operated; MIL-R-587; FSN 3895-234-2542.	Hoist cable.....	80.....	1/2
	Ejection cable.....	70.....	1/2
	Bowl Lift cable.....	60.....	1/2
	Apron Lift cable.....	19.....	9/16
Scraper, earth moving, towed, 12 cu. yd., 4 wheeled, pneumatic tire; I MIL-S-3084; FSN 3805-197- 8582.	Dump cable.....	130.....	1/2
	Hoist cable.....	135.....	1/2
	Tail gate cable.....	135.....	5/8
	Spring pipe cable.....	17.....	5/8
	Sliding sheave to apron cable.....	14' 6".....	7/8
	With bulldozer or angle dozer and front PCU, cable require- ment.	52.....	1/2
Tractor, full tracked, low speed, diesel driven, medium drawbar pull; MIL-T-12229.	With rear PCU.....	72.....	1/2
	With winch, rear mounted, 1 drum.	290.....	1

Table 192. Wire-Rope Connections

Connection	Description	Maximum per- cent of strength of new wire rope
Three clips -----	See figure 94 -----	80.
Basket sockets -----	Made with zinc at 830° F -----	80.
	Made with lead or babbitt metal -----	25 or more.
Thimble in spliced eye (fig. 95).	Rope diameters $\frac{1}{4}$ " -----	100.
	$\frac{3}{8}$ "— $\frac{3}{4}$ " -----	95.
	$\frac{7}{8}$ "—1" -----	90.
	$1\frac{1}{8}$ "— $1\frac{1}{2}$ " -----	80.
	$1\frac{5}{8}$ "—2" -----	75.
	$2\frac{1}{4}$ " and up -----	70.

Table 193. Safe Loads on Chains

Dia of metal (inches)	Approximate weight per 100 feet, pounds	Safe load in tons			
		Wrought iron	High-grade wrought-iron	Soft steel	Special steel
$\frac{3}{8}$ -----	160	1. 35	1. 49	1. 65	3. 20
$\frac{7}{16}$ -----	210	1. 73	1. 90	2. 18	4. 15
$\frac{1}{2}$ -----	280	2. 25	2. 48	2. 63	5. 25
$\frac{5}{8}$ -----	430	3. 47	3. 81	4. 23	7. 60
$\frac{3}{4}$ -----	630	5. 07	5. 58	6. 00	10. 50
$\frac{7}{8}$ -----	840	7. 00	7. 70	8. 25	14. 33
1 -----	1, 100	9. 30	10. 23	10. 60	18. 20

b. Hooks. The safe load in tons for a hook is approximately the square of the diameter in inches of the metal used to make the hook. Dimensions and safe loads for hooks are given more accurately in table 194.

Table 194. Safe Loads on Hooks

Diameter of metal (inches)	Inside diameter of eye (inches)	Width of open- ing (inches)	Safe load (tons)
$\frac{5}{8}$ -----	$\frac{3}{4}$	1	0. 5
$1\frac{1}{16}$ -----	$\frac{7}{8}$	$1\frac{1}{16}$	0. 6
$\frac{3}{4}$ -----	1	$1\frac{1}{8}$	0. 7
$\frac{7}{8}$ -----	$1\frac{1}{8}$	$1\frac{1}{4}$	1. 2
1 -----	$1\frac{1}{4}$	$1\frac{3}{8}$	1. 7
$1\frac{1}{8}$ -----	$1\frac{3}{8}$	$1\frac{1}{2}$	2. 1
$1\frac{1}{4}$ -----	$1\frac{1}{2}$	$1\frac{1}{2}$	2. 5
$1\frac{3}{8}$ -----	$1\frac{5}{8}$	$1\frac{7}{8}$	3. 0
$1\frac{1}{2}$ -----	$1\frac{3}{4}$	$2\frac{1}{16}$	4. 0
$1\frac{5}{8}$ -----	2	$2\frac{1}{4}$	4. 7
$1\frac{7}{8}$ -----	$2\frac{1}{8}$	$2\frac{1}{2}$	5. 5
$2\frac{1}{4}$ -----	$2\frac{3}{4}$	3	6. 8
$2\frac{5}{8}$ -----	$3\frac{1}{8}$	$3\frac{3}{8}$	8. 5
3 -----	$3\frac{1}{2}$	4	12. 0

Section III. CONCRETE AND CONCRETE MATERIALS

185. Concrete Materials

a. Cement. In the United States, portland cement is shipped either in bulk or in paper or cloth bags holding 94 pounds, 1 cubic foot, loose measure. European portland cement is very similar to that made in the United States, but it is shipped in bags of 110 pounds and in some cases in wooden barrels.

b. Fine Aggregate. Fine aggregate consists of well-graded particles $\frac{1}{4}$ inch and smaller. Clay, silt, and dust may not exceed 3 percent by weight of the fine aggregate.

c. Coarse Aggregate. The commonly used coarse aggregates are gravel and crushed rock. They should consist of clean, hard, strong, and curable particles.

d. Reinforcing Rods. (See paragraph 165.)

e. Average Weights of Materials Used in Concrete Construction. Concrete material weights are shown below.

Item	Average weight
Aggregate, coarse.....	2,500 pounds per cubic yard.
Aggregate, fine.....	2,800 pounds per cubic yard.
Aggregate, combined coarse and fine...	2,600 pounds per cubic yard.
Concrete.....	4,000 pounds per cubic yard.
Form lumber.....	3,000 pounds per thousand board measure.
Reinforcing steel, bundled.....	380 pounds per cubic foot.
Reinforcing steel.....	5 to 30 pounds per cubic yard of concrete.

186. Concrete Proportioning

a. Water-Cement Ratio. See table 196.

b. Slump. Table 195 gives a range of suggested values of slump for various types of structure; in making a selection in a particular case, however, consideration must be given to structural details.

c. Coarse Aggregate. Coarse aggregate should be graded up to the maximum size that the nature of the job permits. This depends on the size and shape of the concrete members and on the amount and

Table 195. Slump Values

Type of construction	Slump in inches	
	Maximum	Minimum
Reinforcing foundation walls and footings.....	5	2
Plain footings, caissons, and substructure walls.....	4	1
Slabs, beams, and reinforced walls.....	6	3
Building columns.....	6	3
Pavements.....	3	2
Heavy mass construction.....	3	1

Note. When high-frequency vibrators are used, the tabulated values should be reduced by $\frac{1}{4}$.

distribution of the reinforcing steel. In general it should not exceed either $\frac{1}{2}$ the least dimension of the member or $\frac{3}{4}$ the minimum clear space between reinforcing bars (or between a bar and the nearest form). For a pavement slab it should not exceed $\frac{1}{3}$ the thickness of the slab. A common range of maximum sizes is from $\frac{1}{4}$ inch to 2 inches.

d. Proportions of Mix. Table 196 gives suggested proportions for various combinations of water-cement ratio and the maximum size of aggregate.

e. Adjustment for Moisture. The figures in table 196 are for saturated surface dry aggregates. They will require adjustment if the aggregate, especially the dry aggregate, contains a considerable amount of moisture.

187. Forms

a. Wall Forms. Wall forms (fig. 99) are normally constructed of wood sheathing 1 to 2 inches thick carried on studs and wales. 2 by 4 to 3 by 8 inches. The required stud and wale spacings depend on the concrete temperature, the rate of placing concrete, and the sheathing thickness. They are determined as follows:

- (1) The maximum pressure against wall forms depends upon the concrete temperature and the rate of placing, the latter in feet of height per hour. The pressure resulting from various combinations of these are shown in figure 96.
- (2) With surfaced sheathing of nominal thickness of 1 to 2 inches, the maximum stud spacing for various concrete pressures is shown in figure 97.
- (3) Based on various combinations of sheathing and stud sizes, the maximum wale spacing is similarly shown in figure 98.
- (4) *Example.*
 - (a) *Problem.* One hundred linear feet of concrete wall 1 foot thick is to be placed at a rate of 10 cubic yards per hour at a temperature of 70 °F. What spacings are required for 2- by 4-inch studs and wales, using 1-inch sheathing?
 - (b) *Solution.*

$$\frac{\text{Cubic yards of concrete}}{\text{per foot of wall height}} = \frac{100 \times 1}{27} = 3.7$$

$$\text{Feet of wall height placed per hour} = \frac{10}{3.7} = 2.7$$

Maximum concrete pressure ((1) above) = 400 pounds per square foot

Maximum stud spacing ((2) above) = 19 inches

Maximum wale spacing ((3) above) = 31 inches.

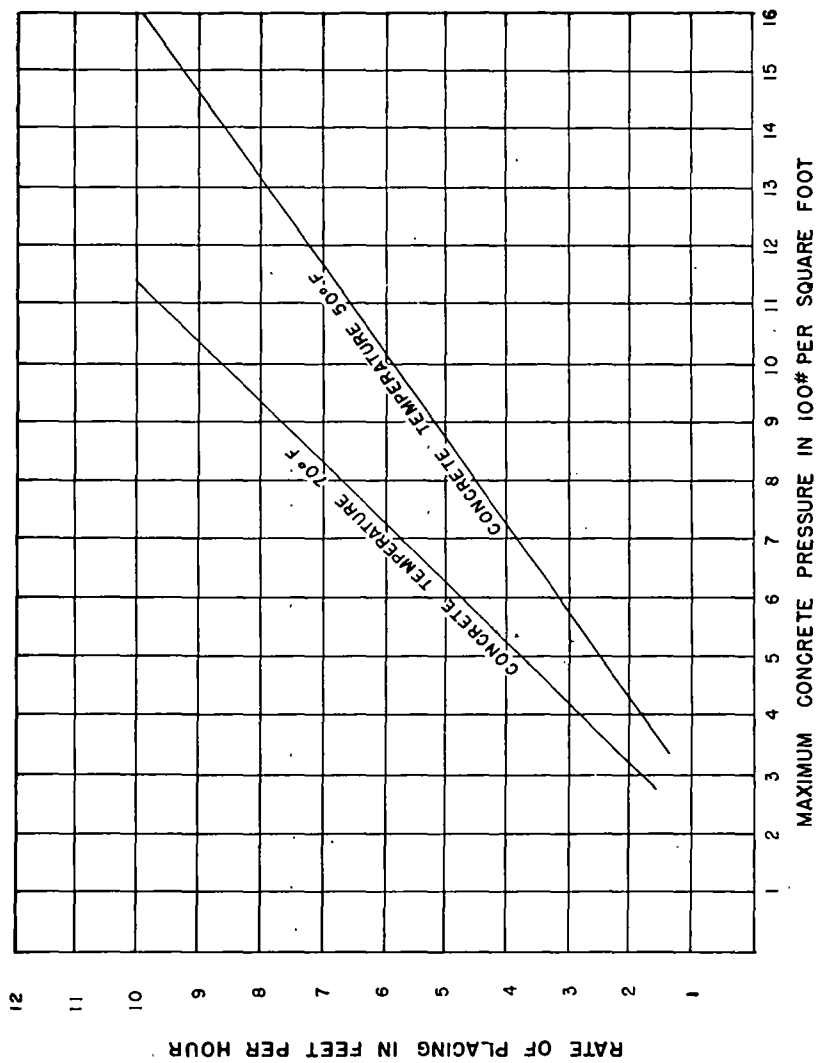


Figure 96. Maximum concrete pressures against wall forms.

Table 196. *Cement Mix Proportions*

With fine sand—fineness modulus 2.20-260

Maximum size of aggregate (inches)	Water (gallons per sack of cement)	Water (gallons per cubic yard of concrete)	Cement (sacks per cubic yard of concrete)	Fine aggregate (percent of total aggregate)	Fine aggregate (pounds per sack of cement)	Coarse aggregate (pounds per sack of cement)	Fine aggregate (pounds per cubic yard of concrete)	Coarse aggregate (pounds per cubic yard of concrete)	Yield (cubic feet of concrete per sack of cement)
$\frac{3}{4}$	5	38	7.6	43	170	230	1,290	1,750	3.56
1	5	37	7.4	38	160	255	1,185	1,890	3.65
$1\frac{1}{2}$	5	35	7.0	34	150	300	1,050	2,100	3.86
2	5	33	6.6	31	150	335	990	2,210	4.09
$\frac{3}{4}$	$5\frac{1}{2}$	38	6.9	44	195	250	1,345	1,725	3.91
1	$5\frac{1}{2}$	37	6.7	39	180	285	1,205	1,910	4.03
$1\frac{1}{2}$	$5\frac{1}{2}$	35	6.4	35	175	320	1,120	2,050	4.22
2	$5\frac{1}{2}$	33	6.0	32	175	370	1,050	2,220	4.50
$\frac{3}{4}$	6	38	6.3	45	225	275	1,420	1,730	4.29
1	6	37	6.2	40	205	305	1,270	1,890	4.36
$1\frac{1}{2}$	6	35	5.8	36	200	355	1,160	2,060	4.66
2	6	33	5.5	33	200	400	1,100	2,200	4.91
$\frac{3}{4}$	$6\frac{1}{2}$	38	5.9	46	245	288	1,445	1,700	4.58
1	$6\frac{1}{2}$	37	5.7	41	230	330	1,310	1,880	4.74
$1\frac{1}{2}$	$6\frac{1}{2}$	35	5.4	37	225	380	1,215	2,050	5.00
2	$6\frac{1}{2}$	33	5.1	34	225	430	1,150	2,195	5.30
$\frac{3}{4}$	7	38	5.4	47	280	315	1,510	1,700	5.00
1	7	37	5.3	42	255	355	1,350	1,880	5.10
$1\frac{1}{2}$	7	35	5.0	38	250	410	1,250	2,050	5.40
2	7	33	4.7	35	250	465	1,175	2,185	5.75

$\frac{3}{4}$	$7\frac{1}{2}$	38	5. 1	48	300	330	1, 530	1, 680	5. 30
1	$7\frac{1}{2}$	37	4. 9	43	285	380	1, 400	1, 860	5. 51
$1\frac{1}{2}$	$7\frac{1}{2}$	35	4. 7	39	275	430	1, 290	2, 020	5. 75
2	$7\frac{1}{2}$	33	4. 4	36	275	495	1, 210	2, 180	6. 14
$\frac{3}{4}$	8	38	4. 8	49	330	345	1, 585	1, 655	5. 63
1	8	37	4. 6	44	315	400	1, 450	1, 840	5. 87
$1\frac{1}{2}$	8	35	4. 4	40	305	455	1, 340	2, 000	6. 14
2	8	33	4. 1	37	310	525	1, 270	2, 150	6. 59
$\frac{3}{4}$	5	38	7. 6	45	180	220	1, 370	1, 670	3. 56
1	5	37	7. 4	40	165	250	1, 220	1, 850	3. 65
$1\frac{1}{2}$	5	35	7. 0	36	160	290	1, 120	2, 030	3. 86
2	5	33	6. 6	33	160	325	1, 055	2, 140	4. 09
$\frac{3}{4}$	$5\frac{1}{2}$	38	6. 9	46	205	240	1, 415	1, 655	3. 91
1	$5\frac{1}{2}$	37	6. 7	41	190	275	1, 270	1, 840	4. 03
$1\frac{1}{2}$	$5\frac{1}{2}$	35	6. 4	37	185	315	1, 185	2, 015	4. 22
2	$5\frac{1}{2}$	33	6. 0	34	185	360	1, 110	2, 160	4. 50
$\frac{3}{4}$	6	38	6. 3	47	235	265	1, 480	1, 670	4. 29
1	6	37	6. 2	42	215	295	1, 335	1, 830	4. 36
$1\frac{1}{2}$	6	35	5. 8	38	210	345	1, 220	2, 000	4. 66
2	6	33	5. 5	35	210	390	1, 155	2, 145	4. 91
$\frac{3}{4}$	$6\frac{1}{2}$	38	5. 9	48	255	280	1, 505	1, 650	4. 58
1	$6\frac{1}{2}$	37	5. 7	43	240	320	1, 370	1, 825	4. 74
$1\frac{1}{2}$	$6\frac{1}{2}$	35	5. 4	39	235	370	1, 270	2, 000	5. 00
2	$6\frac{1}{2}$	33	5. 1	36	235	415	1, 200	2, 120	5. 30

Table 196. *Cement Mix Proportions—Continued*

With fine sand—fineness modulus 2.20-260									
Maximum size of aggregate (inches)	Water (gallons per sack of cement)	Water (gallons per cubic yard of concrete)	Cement (sacks per cubic yard of concrete)	Fine aggregate (percent of total aggregate)	Fine aggregate (pounds per sack of cement)	Coarse aggregate (pounds per sack of cement)	Fine aggregate (pounds per cubic yard of concrete)	Coarse aggregate (pounds per cubic yard of concrete)	Yield (cubic feet of concrete per sack of cement)
¾	7	38	5.4	49	290	305	1,565	1,650	5.00
1	7	37	5.3	44	270	340	1,430	1,800	5.10
1½	7	35	5.0	40	265	395	1,325	1,975	5.40
2	7	33	4.7	37	265	450	1,245	2,120	5.75
¾	7½	38	5.1	50	315	315	1,605	1,605	5.30
1	7½	37	4.9	45	300	365	1,470	1,790	5.51
1½	7½	35	4.7	41	290	415	1,365	1,950	5.75
2	7½	33	4.4	38	290	480	1,275	2,110	6.14
¾	8	38	4.8	51	345	330	1,660	1,585	5.63
1	8	37	4.6	46	330	385	1,520	1,770	5.87
1½	8	35	4.4	42	320	440	1,410	1,935	6.14
2	8	33	4.1	39	325	510	1,330	2,090	6.59
¾	5	38	7.6	47	185	210	1,370	1,595	3.56
1	5	37	7.4	42	175	240	1,295	1,775	3.65
1½	5	35	7.0	38	170	280	1,190	1,960	3.86
2	5	33	6.6	35	170	315	1,120	2,080	4.09
¾	5½	38	6.9	48	215	230	1,480	1,585	3.91
1	5½	37	6.7	43	200	265	1,340	1,775	4.03
1½	5½	35	6.4	39	195	305	1,250	1,950	4.22
2	5½	33	6.0	36	195	350	1,170	2,100	4.50

$\frac{3}{4}$	6	38	6.3	49	245	255	1,540	1,610	4.29
1	6	37	6.2	44	225	285	1,395	1,770	4.36
$1\frac{1}{2}$	6	35	5.8	40	225	335	1,305	1,945	4.66
2	6	33	5.5	37	220	380	1,210	2,090	4.91
$\frac{3}{4}$	$6\frac{1}{2}$	38	5.9	50	265	265	1,560	1,560	4.58
1	$6\frac{1}{2}$	37	5.7	45	250	310	1,425	1,765	4.74
$1\frac{1}{2}$	$6\frac{1}{2}$	35	5.4	41	250	355	1,350	1,920	5.00
2	$6\frac{1}{2}$	33	5.1	38	250	405	1,275	2,065	5.30
$\frac{3}{4}$	7	38	5.4	51	300	290	1,620	1,565	5.00
1	7	37	5.3	46	280	330	1,485	1,750	5.10
$1\frac{1}{2}$	7	35	5.0	42	270	385	1,350	1,925	5.40
2	7	33	4.7	39	280	435	1,315	2,045	5.75
$\frac{3}{4}$	$7\frac{1}{2}$	38	5.1	52	330	300	1,685	1,530	5.30
1	$7\frac{1}{2}$	37	4.9	47	310	355	1,520	1,740	5.51
$1\frac{1}{2}$	$7\frac{1}{2}$	35	4.7	43	305	400	1,435	1,880	5.75
2	$7\frac{1}{2}$	33	4.4	40	305	465	1,340	2,045	6.14
$\frac{3}{4}$	8	38	4.8	53	360	315	1,730	1,510	5.63
1	8	37	4.6	48	345	370	1,590	1,700	5.87
$1\frac{1}{2}$	8	35	4.4	44	335	425	1,475	1,870	6.14
2	8	33	4.1	41	340	480	1,395	2,010	6.59

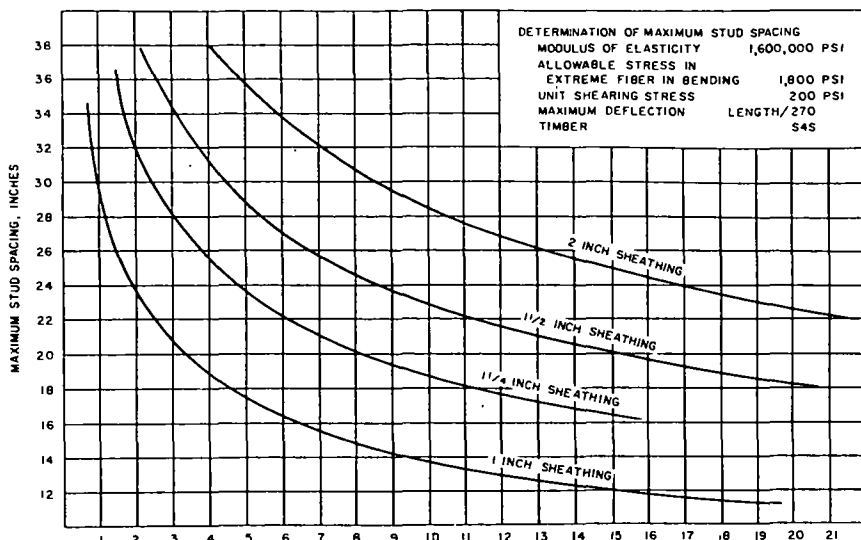


Figure 97. Maximum stud spacing for wall forms.

b. *Slab Forms.* Slab forms are designed to carry the full load of freshly placed concrete.

c. *Column Forms.* Column forms are built as shown in figure 100, with yokes of 2- by 4-inch lumber spaced as shown in figure 101.

d. *Anchor Bolts.* For buildings and in other light construction, anchor bolts are installed as shown in figure 102, with the upper

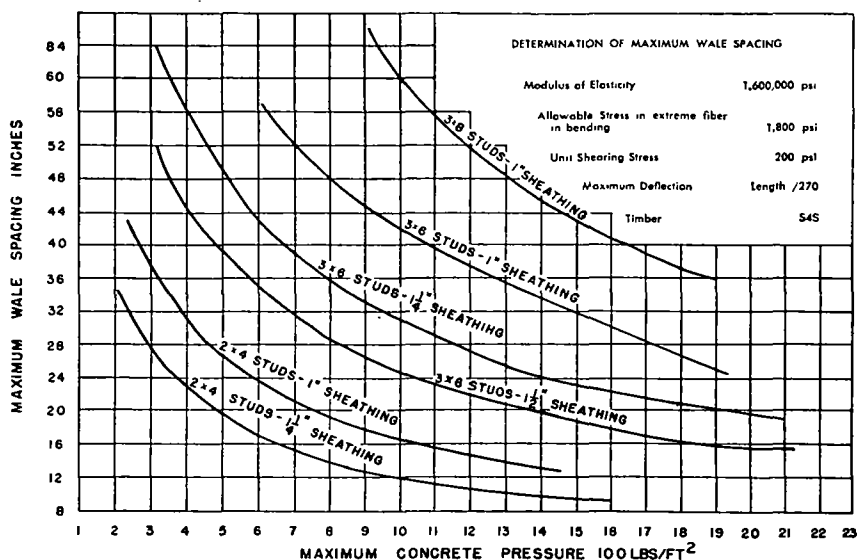


Figure 98. Maximum wale spacing for wall forms.

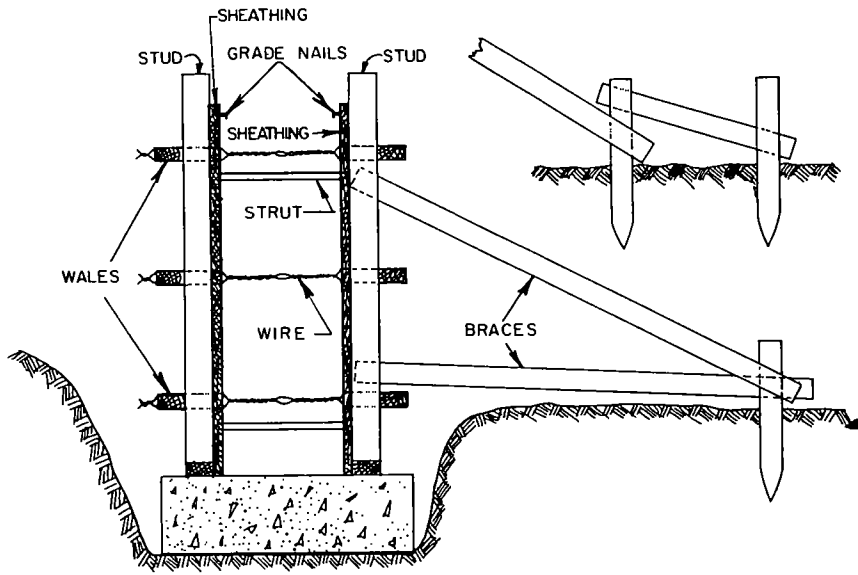


Figure 99. Wall forms and braces.

part of each enclosed in a 6-inch length of pipe or sheet-metal tubing to permit a slight lateral adjustment in bolt positioning.

e. Steel Pavement Forms.

- (1) Standard steel pavement forms are rapidly and accurately set and should be used when obtainable. They are made

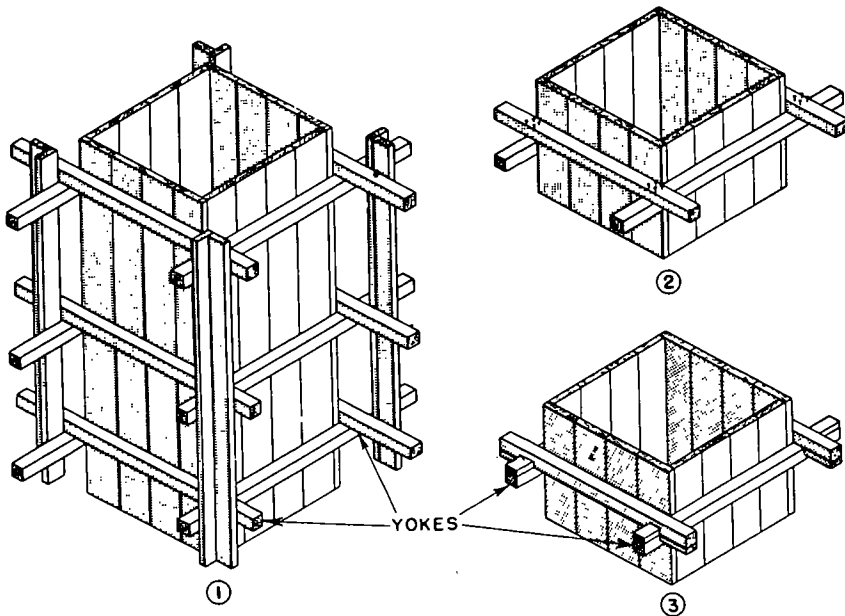


Figure 100. Column forms.

LARGEST DIMENSION OF COLUMN IN INCHES $\alpha/$

HEIGHT	16"	18"	20"	24"	28"	30"	32"	36"
1'								
2'	31"	29"	27"	23"	21"	20"	19"	17"
3'	31"	28"	26"	23"	20"	19"	18"	17"
4'	31"	28"	26"	23"	20"	19"	18"	17"
5'	31"	28"	26"	23"	20"	19"	18"	17"
6'	30"	28"	26"	23"	20"	18"	17"	15"
7'	30"	28"	26"	22"	18"	18"	17"	15"
8'	29"	26"	24"	22"	15"	18"	13"	12"
9'	29"	26"	19"	16"	13"	12"	10"	8"
10'	21"	20"	19"	14"	12"	10"	10"	8"
11'	21"	18"	16"	13"	9"	8"	8"	7"
12'	21"	18"	16"	12"	9"	8"	8"	7"
13'	20"	16"	15"	11"	9"	7"	7"	6"
14'	18"	15"	14"	10"	8"	7"	6"	6"
15'	18"	13"	12"	9"	8"	6"	6"	6"
16'	15"	12"	11"	9"	7"	6"	6"	6"
17'	14"	12"	11"	9"	7"	6"	6"	6"
18'	13"	11"	10"	8"	7"	6"	6"	6"
19'	13"	11"	10"	8"	7"	6"	6"	6"
20'	13"	11"	10"	8"	7"	6"	6"	6"

$\alpha/$ **EXAMPLE:** TO FIND THE YOKE SPACING FOR A 12-FOOT COLUMN THE LARGEST DIMENSION OF WHICH IS 16 INCHES, READ UP FROM 12-FOOT HEIGHT IN THE COLUMN HEADED 16 INCHES. YOKES ARE SPACED AT 21 INCHES, 29 INCHES, 30 INCHES AND 31 INCHES.

Figure 101. Yoke spacing for various sizes and heights of columns.

of $\frac{3}{16}$ -inch steel plate in sections 10 feet long. Forms for slab thicknesses of 6, 7, 8, 9, 10, and 12 inches can normally be obtained in the zone of interior. The usual base-plate width is 8 inches. The base-plate width should be equal to or greater than the face depth. Locking plates rigidly join the ends of the sections. Three steel stakes, 1 inch in diameter, per 10-foot section of form are required.

- (2) After the stakes are driven, the form is set true to line and grade and clamped to the stakes by special splines and wedges. Forms are set on the subgrade ahead of the paver

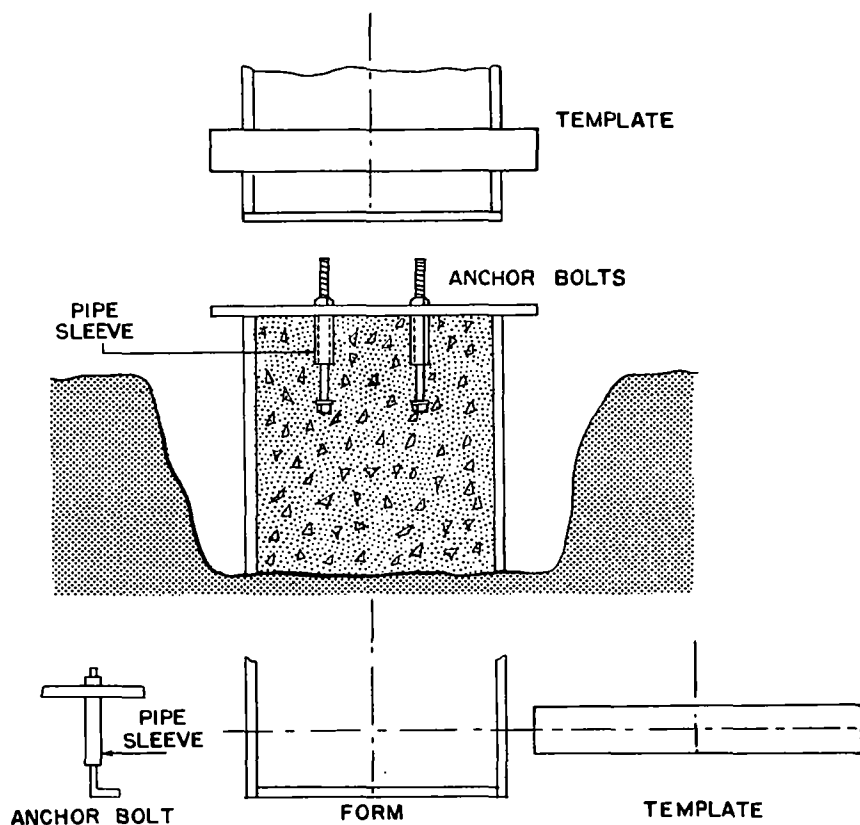


Figure 102. Installation of anchor bolts.

and must be left in place for at least 24 hours after the concrete is placed.

- (3) The forms must be oiled just before the concrete is placed. After a form is completely oiled, the top side or traction edge must be wiped free of oil.
- (4) The forms are removed as soon as practicable, cleaned, oiled, and stacked in neat piles ready for reuse.

Section IV. BITUMINOUS CONSTRUCTION MATERIALS

188. Bituminous Materials

Table 197 lists the principal asphalt and tar products used in paving, with their source, form in which marketed, grade designation, temperature of application, and other data.

189. Bituminous Surface Treatment

Table 198 gives the gradation requirements for aggregates. Tables 199 and 200 give the quantities of aggregate and bitumen for single-surface and double-surface treatments, respectively.

Table 197. Bituminous Materials

Material	Source	Form	Grade designation	Temperature of application		Remarks
				Spraying (° F.)	Mixing (° F.)	
Cutback asphalts (RC and MC).	Product of refining crude petroleum oils containing asphalt.	Liquids, asphalt res- idues fluxed with more volatile petro- leum distillates.	Rapid curing			Naphtha or gasoline (highly volatile), evaporating quickly and leaving asphalt-cement binder. Permits early use of surface. Inflammable. Keep open flame away from storage tanks and drums.
			RC-0	50°-120°	50°-120°	
			RC-1	80°-150°	80°-125°	
			RC-2	100°-175°	80°-150°	
			RC-3	150°-200°	125°-175°	
			RC-4	175°-250°	150°-200°	
			RC-5	200°-275°	175°-225°	
			Medium curing			
			MC-0	50°-120°	50°-120°	
			MC-1	80°-150°	80°-150°	
			MC-2	100°-200°	100°-200°	
			MC-3	175°-250°	150°-200°	
			MC-4	200°-275°	175°-225°	
			MC-5	225°-275°	200°-250°	
			Asphalt road oils (SC).	Products of refining crude petroleum oils containing asphalt.	Liquids, low volatile oils left or blended with asphalt resi- dues near end of refining process.		Slow curing			Slow curing.
SC-0	50°-120°	50°-120°				
SC-1	80°-200°	80°-200°				
SC-2	150°-200°	150°-200°				
SC-3	175°-250°	175°-250°				
SC-4	175°-250°	175°-250°				
SC-5	200°-275°	200°-275°				

Asphaltic cements (AC) or paving asphalts.	do-----	Semiliquids or solids	40-50 ¹ 50-60 ¹ 60-70 ¹ 70-80 ¹ 85-100 ¹ 100-120 ¹ 120-150 ¹ 150-200 ¹ 200-300 ¹	275°-350°	275°-325°	Penetration 40 to 100 used for crack and joint fillers. Penetrations 70 to 300 used for plant mixes, penetration macadam, and surface treatment. Comparable grades, Federal Specification SS-A-706b: 50-60 penetration, AP-5; 85-100 penetration, AP-3; 100-120 penetration, AP-2; 120-150 penetration, AP-1.
Powdered asphalt (PA).	do-----	Hard and solid asphalts ground to powder.		275°-350°	200°-275°	Used with SC oils to produce extra tough road surfaces.
Asphalt emulsions (AE).	Asphalt cements in water with an emulsifying agent.	Liquids-----	Rapid, medium, and slow setting			Freezing destroys emulsion, penetration, and surface treatments. Road and plant mixes with coarse aggregate. Road and plant mixes with fine aggregate. Grades and typical uses of asphalt emulsions under Federal Specification SS-A-674a are as follows: Grade I, Surface treatments, seal coats. Grade II, Open-graded coarse aggregate mixed-in-place. Grade III, Summer use in bituminous concrete mixtures for repair work. Grade IV, Winter use in bituminous concrete mixtures for repair work. Grade V, Penetration macadam and surface treatments. Grade VI, Fine aggregate mixes in which a substantial quantity of aggregate passes 1/8-inch sieve and a portion may pass a No. 200 sieve.
			RS-1 MS-1 MS-2 MS-3 SS-1 SS-2	50°-140°	50°-140°	

¹ Penetrations of 100, 120, 150, 200, and 300 show increasing softness of fluidity. Penetrations of 85, 70, 60, 50, 40, and so on, showing increasing hardness or solidity road oil SC5 (with high viscosity) and the softest paving asphalts both have penetrations of about 200.

Table 197. Bituminous Materials—Continued

Material	Source	Form	Grade designation	Temperature of application		Remarks
				Spraying (° F.)	Mixing (° F.)	
			Rapid, medium, and slow setting			
Road tar (RT) priming oils.	All road tars are refined byproducts of coking coal or manufacture of water gas.	do.	RT-1	60°-125°		Priming oils.
			RT-1	60°-125°		
			RT-3	80°-150°		
Cold tars (TC)	do.	do.	RT-4	80°-150°		Cold tars for road mix and patching.
			RT-5	80°-150°		
			RT-6	80°-150°		
Hot tars (TH)	do.	Nonliquids	RT-7	150°-225°		Hot tars for plant mix, seal coats, penetration macadam, crack fillers, etc.
			RT-8	150°-225°		
			RT-9	150°-225°		
			RT-10	175°-250°		
			RT-11	175°-250°		
Cutback tars (RTCB).	Tars combined with volatile distillates from coal- or water-gas tar.	Liquids	RT-12	175°-250°		Patching mixtures. Inflammable. Keep open flame away from storage tanks and drums.
			RTCB-5	60°-120°		
			RTCB-6	60°-120°		
Rock asphalt	Natural combinations of asphalt with sand or stone.	Solids				Mined and used locally where found with cutbacks added if needed.

Table 198. Gradation Requirements for Aggregates for Bituminous Surface Treatments

Sieve designation	Percent passing each sieve (square opening) by weight								
	Gradation designations								
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6 ¹	No. 7 ¹	No. 8 ¹	No. 9 ¹
1½-inch.....	100								
1-inch.....	90-100	100	100						
¾-inch.....	40-75	90-100	90-100	100	100				
½-inch.....	15-35	20-55		90-100	90-100	100			
⅜-inch.....	0-15	0-15	20-55	40-70	40-75	85-100	100		100
No. 4.....	0-5	0-5	0-10	0-15	5-25	10-30	85-100	100	95-100
No. 8.....			0-5	0-5	0-5	0-10	10-40	50-100	
No. 10.....								0-5	
No. 16.....							0-10		45-80
No. 50.....									5-30
No. 100.....									0-8

¹ Clean sand may be used instead of crushed aggregates.

Table 199. Quantities of Aggregate and Bitumen for Single Surface Treatments

Material	Unit of measurement	No. 2	Gradation designations					
			No. 3	No. 4	No. 5	No. 6	No. 8	No. 9
Aggregate.....	Pounds per square yard..	35-45	35-45	25-35	25-35	15-25	10-20	10-15
Bitumen.....	Gallons per square yard..	0. 35-0. 45	0. 35-0. 45	0. 25-0. 35	0. 25-0. 35	0. 15-0. 25	0. 10-0. 20	0. 10-0. 15

Table 200. Quantities of Aggregate and Bitumen for Double Surface Treatments

Gradation designations	Bitumen (gallons per square yard), first application	Aggregate (pounds per square yard), first spreading	Bitumen (gallons per square yard), first spreading	Aggregate (pounds per square yard), second spreading
No. 1-----	0. 45-0. 55	45-55	-----	-----
No. 4-----	-----	-----	0. 2-0. 3	15-25
No. 2-----	0. 40-0. 50	40-50	-----	-----
No. 6-----	-----	-----	0. 2-0. 3	15-25
No. 4-----	0. 35-0. 45	35-45	-----	-----
No. 7-----	-----	-----	0. 2-0. 3	15-25

190. Gradation Control and Bituminous Content

Table 201 gives recommended limits for gradation control, and suggested bituminous content for each gradation, for asphaltic surface courses. Tables 202, 203, and 204 give similar data for asphaltic binder courses, asphaltic base courses, and tar mixes.

Section V. SOILS

191. General

For the control of soils in military construction, see TM 5-541. For data on soil classification and classification tests, the properties and engineering characteristics of soils, and soil surveys, see FM 5-250.

192. Soil Classification

Figure 103 gives the Unified Soil Classification system.

193. Identification of Soils

Figure 104 gives a summary of identification procedure, using laboratory test results.

194. Pertinent Characteristics of Soils

Figure 105 summarizes the characteristics of soils which are pertinent to road and airfield construction. Figure 106 gives similar data pertaining to embankment and foundation construction.

Section VI. MISCELLANEOUS BUILDING MATERIALS AND HARDWARE

195. Wallboard, Insulation: Substitutes

Nomenclature, sizes, types and logistical data are given in table 205.

UNIFIED SOIL CLASSIFICATION (Including Identification and Description)							
Major Divisions	Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 inches and basing fractions on estimated weights)	Information Required for Describing Soils	Laboratory Classification Criteria		
Coarse-grained Soils More than half of material is larger than No. 200 sieve size	Gravels More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	For undisturbed soils add information on stratification, degree of compac- tation, cementation, moisture conditions and drainage characteristics Give typical name, indicate approximate percentages of sand and gravel, max size, angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses. Example Silty sand, gravelly, about 20% hard, angular gravel particles 1/2-in. maximum size, rounded and subangular sand grains coarse to fine, about 15% nonplastic fines with low dry strength, well compacted and moist in place, al- luvial sand, (SM)	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_g = \frac{D_{60}}{D_{10} \times 60}$ Between one and 3 Not meeting all gradation requirements for GW	
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing			Atterberg limits below "A" line or PI less than 4
		GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below)		Atterberg limits above "A" line with PI greater than 7	
		GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below)		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_g = \frac{D_{60}}{D_{10} \times 60}$ Between one and 3 Not meeting all gradation requirements for SW	
	SW	Well-graded sands, gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate particle sizes	Atterberg limits below "A" line or PI less than 4			
	SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing	Atterberg limits above "A" line with PI greater than 7			
	Sands More than half of coarse fraction is smaller than No. 4 sieve size (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines of fines with low plasticity (for identification procedures see ML below)		Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols	
		SC	Clayey sands, sand-clay mixtures	Plastic fines (for identification procedures see CL below).			
		Fine-grained Soils More than half of material is smaller than No. 200 sieve size The No. 200 sieve size is about the smallest particle visible to the naked eye	Identification Procedures on Fraction Smaller than No. 40 Sieve Size			Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color is wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. Example Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).	
			ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None
	CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
	OL		Organic silts and organic silty clays of low plasticity	Slight to medium	Slow	Slight	
	MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Slight to medium	Slow to none	Slight to medium	
	CH		Inorganic clays of high plasticity, fat clays	High to very high	None	High	
OH	Organic clays of medium to high plasticity, organic silts.		Medium to high	None to very slow	Slight to medium		
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soils	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		

(1) Boundary classification Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder

(2) All sieve sizes on this chart are U S standard

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRADED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests

Dilatancy (Reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky. Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction

Dry Strength (Crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour

Toughness (Consistency near plastic limit)

After removing particles larger than the No. 40 sieve size, a specimen of silt about one-half inch cube in size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

High organic clays have a very weak and spongy feel at the plastic limit

Adopted by Corps of Engineers and Bureau of Reclamation, January 1952

- (1) **Boundary classifications** Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder.
- (2) All sieve sizes on this chart are U.S. standard

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shearing)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky. Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit)

After removing particles larger than the No. 40 sieve size, a specimen of silt about one-half inch cubed in size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. The specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

High organic clays have a very weak and spongy feel at the plastic limit.

Figure 103. Unified Soil Classification system.

Table 201. Recommended Limits for Gradation Control and Suggested Bitumen Content for Each Gradation, Asphaltic Surface Courses

Maximum particle size (inches)	Gradation No.	Recommended bitumen	Percent passing each sieve, by weight										
			Sieve designation										
			1½ in.	1 in.	¾ in.	½ in.	⅜	No. 4	No. 10	No. 20	No. 40	No. 80	No. 200
1½-----	1	4.5- 6.0	100	84-100	-----	66-75	-----	42-54	31-43	-----	16-25	10-17	4.0- 7.5
	2	5.0- 6.5	100	87-100	-----	70-79	-----	48-60	37-49	-----	20-29	12-19	4.5- 7.5
	3	5.5- 7.0	100	90-100	-----	75-84	-----	54-66	43-55	-----	25-34	15-22	5.0- 8.0
1-----	1	5.0- 6.0	-----	100	85-100	72-87	-----	45-60	32-47	-----	16-26	10-18	4.0- 8.0
	2	5.0- 6.5	-----	100	87-100	76-89	-----	52-67	39-54	-----	21-32	13-21	4.5- 8.5
	3	5.5- 7.0	-----	100	90-100	82-93	-----	60-75	47-62	-----	26-37	16-24	5.0- 9.0
	¹ HP	5.0- 6.5	-----	100	89-100	78-90	69-83	55-70	42-56	30-43	22-33	14-22	3.0- 6.0
¾-----	1	5.0- 6.0	-----	-----	100	86-100	-----	55-67	40-54	-----	22-31	12-20	4.0- 8.0
	2	5.5- 6.5	-----	-----	100	89-100	-----	61-74	46-60	-----	26-35	15-23	4.5- 8.5
	3	6.0- 7.5	-----	-----	100	91-100	-----	67-80	54-66	-----	31-40	19-26	5.0- 9.0
	¹ HP	5.5- 6.5	-----	-----	100	86-100	78-90	60-73	43-57	29-43	19-33	10-20	3.0- 6.0
½-----	1	5.0- 6.5	-----	-----	-----	100	84-100	60-73	43-57	-----	23-33	13-20	4.0- 8.0
	2	6.0- 7.5	-----	-----	-----	100	86-100	66-79	50-64	-----	27-37	16-23	4.5- 8.5
	3	6.0- 8.0	-----	-----	-----	100	89-100	73-85	57-70	-----	31-42	19-26	5.0- 9.0
⅜-----	1	6.0- 9.0	-----	-----	-----	-----	100	78-100	56-76	-----	26-44	14-28	6.0-10.0
	2	7.0-10.0	-----	-----	-----	-----	100	80-100	60-80	-----	29-47	16-30	7.0-11.0
	3	8.0-11.0	-----	-----	-----	-----	100	82-100	64-84	-----	32-50	18-32	8.0-12.0

¹ HP indicates gradation for high-pressure tire traffic and potential jet aircraft pavements.

Table 202. Recommended Limits for Gradation Control and Suggested Bitumen Content for Each Gradation, Asphaltic Binder Courses

Maximum particle size (inches)	Gradation No.	Recommended percent bitumen	Percent passing each sieve, by weight										
			Sieve designation										
			2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 16	No. 40	No. 80	No. 200
2-----	1	3. 5-5. 0	100	86-100	70-84	-----	52-67	-----	32-47	20-35	10-20	6-14	3-7
	2	3. 5-5. 0	100	88-100	72-86	-----	54-69	-----	34-49	22-37	11-21	6-14	3-7
	3	3. 5-5. 0	100	90-100	74-88	-----	57-72	-----	37-52	25-40	12-22	7-15	3-7
1½-----	1	4. 0-6. 0	-----	100	78-100	-----	56-73	-----	35-51	23-38	11-21	6-14	3-7
	2	4. 0-6. 0	-----	100	81-100	-----	59-77	-----	39-55	27-42	13-23	7-15	3-7
	3	4. 0-6. 0	-----	100	84-100	-----	63-80	-----	42-58	31-46	15-25	8-16	3-7
1-----	1	4. 0-6. 0	-----	-----	100	76-100	64-82	-----	38-54	25-41	12-23	7-16	4-8
	2	4. 0-6. 0	-----	-----	100	80-100	67-85	-----	43-59	29-45	14-25	8-17	4-8
	3	4. 0-6. 0	-----	-----	100	85-100	71-89	-----	48-64	34-50	17-28	10-18	4-8
¾-----	1	4. 5-7. 0	-----	-----	-----	100	74-100	60-80	42-60	28-46	14-26	8-18	4-8
	2	4. 5-7. 0	-----	-----	-----	100	80-100	64-84	47-65	33-51	16-28	9-19	4-8
	3	4. 5-7. 0	-----	-----	-----	100	82-100	68-88	52-70	36-54	18-30	10-20	4-8
½-----	1	4. 5-7. 0	-----	-----	-----	-----	100	74-100	50-71	32-53	16-29	10-20	4-9
	2	4. 5-7. 0	-----	-----	-----	-----	100	78-100	54-75	36-57	18-31	11-21	4-9
	3	4. 5-7. 0	-----	-----	-----	-----	100	82-100	59-80	41-62	21-34	12-22	4-9

Table 203. Recommended Limits for Gradation Control and Suggested Bitumen Content for Each Gradation, Asphaltic Base Courses

Maximum particle size (inches)	Recommended percent bitumen	Percent passing each sieve, by weight											
		Sieve designation											
		2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	¾ in.	No. 4	No. 10	No. 40	No. 80	No. 200
2½-----	4. 0-6. 5	100	90-100	80-94	-----	56-76	-----	-----	30-50	20-37	10-24	6-18	0-5
2-----	4. 0-6. 5	-----	100	88-100	-----	62-82	-----	-----	33-53	23-40	12-26	6-18	0-5
1½-----	4. 0-7. 0	-----	-----	100	82-100	70-89	60-80	-----	37-57	25-43	14-28	8-20	0-8

Table 204. Recommended Limits for Gradation Control and Suggested Bitumen Content for Each Gradation, Tar Mixes.

Maximum particle size, in.	Gradation No.	Recommended percent bitumen	Percent passing each sieve, by weight										
			Sieve designation										
			2 in.	1½ in.	1 in.	¾ in.	½ in.	¾ in.	No. 4	No. 10	No. 40	No. 80	No. 200
Surface Courses													
1-----	1	¹ 6. 0- 8. 5	-----	-----	100	85-100	-----	60-75	40-58	25-43	10-20	5-13	2-8
	2	-----	-----	-----	100	85-100	-----	65-82	47-65	32-48	15-25	8-15	4-10
	3	² 7. 5- 9. 5	-----	-----	100	90-100	-----	73-85	54-70	37-55	18-30	10-20	4-10
¾-----	1	¹ 6. 5- 8. 5	-----	-----	-----	100	85-100	70-85	50-66	35-50	15-25	7-15	4-10
	2	-----	-----	-----	-----	100	85-100	75-90	58-73	40-55	20-30	10-18	4-10
	3	² 7. 5-10	-----	-----	-----	100	90-100	80-93	65-80	50-65	25-35	12-20	6-10
½-----	1	¹ 6. 5- 8. 5	-----	-----	-----	-----	100	82-100	55-70	35-50	13-24	7-14	4-10
	2	-----	-----	-----	-----	-----	100	85-100	65-80	45-60	18-29	10-19	4-10
	3	² 8. 0-10	-----	-----	-----	-----	100	90-100	70-84	50-66	24-35	12-21	6-10
Binder Course													
1½-----	-----	¹ 4. 0- 5. 5	-----	100	75-100	-----	45-75	-----	20-45	10-30	0-10	0-5	-----
	-----	² 5. 0- 6. 5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Base Courses													
2½-----	-----	2. 5- 5. 0	³ 80-100 100	60-85	40-70	-----	15-50	-----	5-25	0-15	0-5	-----	-----
2-----	-----	2. 5- 5. 0	-----	80-100	55-85	-----	20-60	-----	5-30	0-15	0-5	-----	-----
1½-----	-----	2. 5- 5. 0	-----	100	66-100	-----	20-65	-----	5-35	0-20	0-5	-----	-----

¹ Stone or gravel. ² Slag. ³ 100 percent passing 2½-inch sieve.

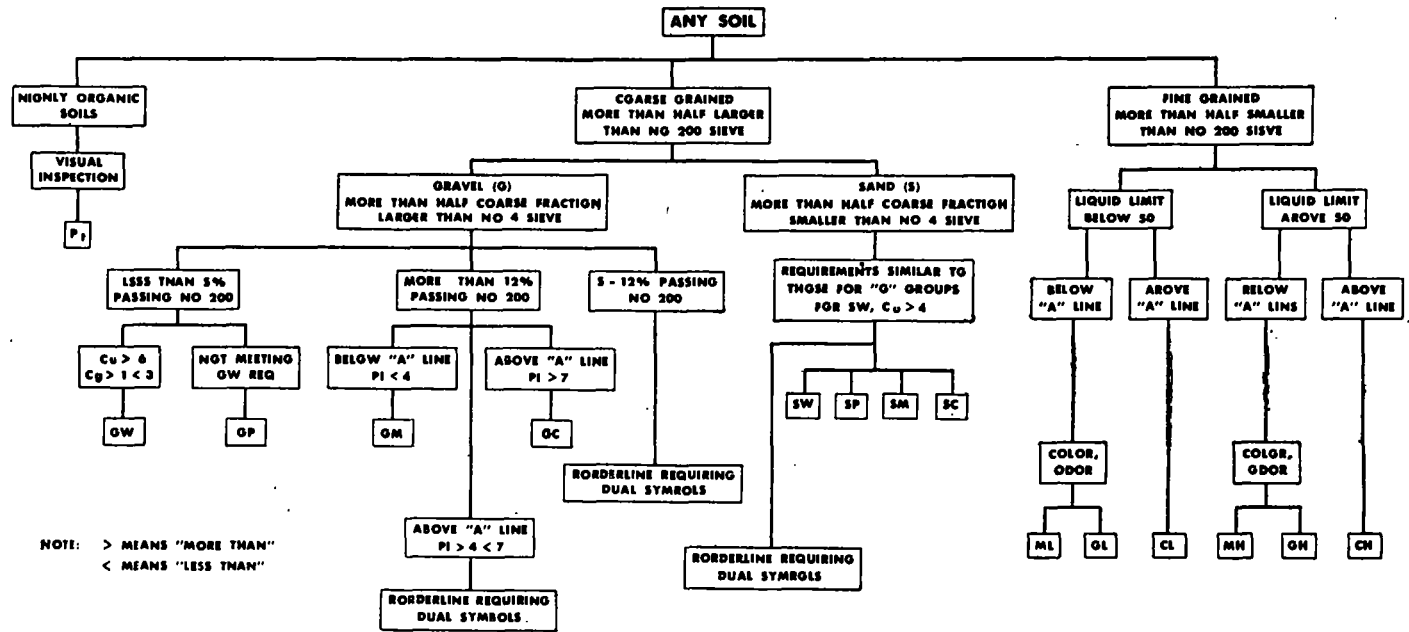


Figure 104. Identification procedure for soils using laboratory test results.

Table 205. Logistical Data, Wallboard and Other Building Materials

	Sizes			Unit measure	Units per container	Type of container	One filled container		Common names
	Thick-ness	Width	Length				Weight (pounds)	Cubic feet	
Board, masonite, tempered-----	1/4"	48"	96"	Sheet-----	50	Box----	3, 520	116. 28	Hardboard. Tempered masonite.
	1/4"	48"	144"	Sheet-----	5	Case----	450	13. 62	
Cement, bituminous plastic, asphaltic base.	1 lb can-----			Pound-----	1	Can----	1	0. 23	Roof cement.
	50 lb can-----			Pound-----	50	Can----	53	1. 08	
Felt, roofing, asphalt saturated, .15 lb, Type I.	-----	36"	144"	Roll-----	3	Crate--	217	8. 06	Tarpaper. Roofing felt.
Fiber board, insulating, roof board, Class C.	1/2"	48"	96"	Sheet-----	6	Crate--	218	15. 21	Roof insulation. Wallboard. Celotex.
	1/2"	48"	120"	Sheet-----	6	Crate--	235	21. 96	
	1/2"	48"	144"	Sheet-----	14	Box----	662	39. 05	
Glass substitute, reinforced-----	-----	36"	100'	Square yard.	33 1/3	Carton.	43	0. 93	
	-----	48"	198'	Square yard.	88	Box----	160	5. 58	
Roof coating, asphalt, fibrous, brushing consistency.	5 gal can-----			Gallon-----	5	Can----	43	1. 08	Roof paint.
	50 gal drum-----			Gallon-----	50	Drum--	485	11. 67	
Wallboard, composition-----	3/8"	48"	96"	Sheet-----	-----	-----	¹ 41	-----	Wallboard. Insulating board.

¹ Weight per sheet, uncrated.

Major Divisions (1) (2)		Letter (3)	Symbol		Name (6)	Value as Foundation When Not Subject to Frost Action (7)	Value as Base Directly under Bituminous Pavement (8)	Potential Frost Action (9)	Compressibility and Expansion (10)	Drainage Characteristics (11)	Compaction Equipment (12)	Unit Dry Weight Lb Per Cu Ft (13)	Field (CBR) (14)	Subgrade Modulus k _s Lb Per Cu In. (15)	
			Hatching (4)	Color (5)											
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment, steel-wheeled roller	125-140	60-80	300 or more	
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Poor to fair	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment, steel-wheeled roller	110-130	25-60	300 or more	
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Fair to good	Slight to medium	Very slight	Fair to poor	Rubber-tired equipment, sheepfoot roller; close control of moisture	130-145	40-80	300 or more	
						Good	Poor	Slight to medium	Slight	Poor to practically impervious	Rubber-tired equipment, sheepfoot roller	120-140	20-40	200 to 300	
	GC		Clayey gravels, gravel-sand-clay mixtures	Good	Poor	Slight to medium	Slight	Poor to practically impervious	Rubber-tired equipment, sheepfoot roller	120-140	20-40	200 to 300			
	SAND AND SANDY SOILS	SW		Red	Well-graded sands or gravelly sands, little or no fines	Good	Poor	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment	110-130	20-40	200 to 300	
		SP			Poorly graded sands or gravelly sands, little or no fines	Fair to good	Poor to not suitable	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment	100-120	10-25	200 to 300	
		SM		Yellow	Silty sands, sand-silt mixtures	Good	Poor	Slight to high	Very slight	Fair to poor	Rubber-tired equipment, sheepfoot roller; close control of moisture	120-135	20-40	200 to 300	
						Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired equipment, sheepfoot roller	105-130	10-20	200 to 300	
	SC		Clayey sands, sand-clay mixtures	Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired equipment, sheepfoot roller	105-130	10-20	200 to 300			
	FINE GRAINED SOILS	SILTS AND CLAYS LL 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sand, or clayey silt with slight plasticity	Fair to poor	Not suitable	Medium to very high	Slight to medium	Fair to poor	Rubber-tired equipment, sheepfoot roller; close control of moisture	100-125	5-15	100 to 200
			CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Fair to poor	Not suitable	Medium to high	Medium	Practically impervious	Rubber-tired equipment, sheepfoot roller	100-125	5-15	100 to 200
			OL			Organic silts and organic silt-clays of low plasticity	Poor	Not suitable	Medium to high	Medium to high	Poor	Rubber-tired equipment, sheepfoot roller	90-105	4-8	100 to 200
		SILTS AND CLAYS LL 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable	Medium to very high	High	Fair to poor	Sheepsfoot roller	80-100	4-8	100 to 200
CH				Inorganic clays of high plasticity, fat clays		Poor to very poor	Not suitable	Medium	High	Practically impervious	Sheepsfoot roller	90-110	3-5	50 to 100	
OH				Organic clays of medium to high plasticity, organic silts		Poor to very poor	Not suitable	Medium	High	Practically impervious	Sheepsfoot roller	80-105	3-5	50 to 100	
HIGHLY ORGANIC SOILS		Pt		Orange	Peat and other highly organic soils	Not suitable	Not suitable	Slight	Very high	Fair to poor	Compaction not practical	-	-	-	

Notes:

- Column 3, Division of GM, and SM groups into subdivisions of d and u are for roads and airfields only, subdivision is on basis of Atterberg limits; suffix d (e.g., GMD) will be used when the liquid limit is 25 or less and the plasticity index is 6 or less, the suffix u will be used when the liquid limit is greater than 25.
- Column 7, values are for subgrades and base courses except for base course directly under bituminous pavement.
- In column 8, the term "excellent" has been reserved for base materials consisting of high quality processed crushed stone.
- In column 9, these soils are susceptible to frost as indicated under conditions favorable to frost action described in the text.
- In column 12, the equipment listed will usually produce the required densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled. In some instances, several types of equipment are listed, because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.
 - Processed base materials and other angular materials. Steel-wheeled rollers are recommended for hard angular materials with limited fines or screenings. Rubber-tired equipment is recommended for softer materials subject to degradation.
 - Finishing. Rubber-tired equipment is recommended for rolling during final shaping operations for most soils and processed materials.
 - Equipment size. The following sizes of equipment are necessary to assure the high densities required for airfield construction:
 - Crawler-type tractor -- total weight in excess of 30,000 lb.
 - Rubber-tired equipment -- wheel load in excess of 15,000 lb, wheel loads as high as 40,000 lb may be necessary to obtain the required densities for some materials (based on contact pressure of approximately 65 to 150 psi).
 - Sheepsfoot roller -- unit pressure (on 6- to 12-sq.-in. foot) to be in excess of 250 psi and unit pressures as high as 650 psi may be necessary to obtain the required densities for some materials. The area of the feet should be at least 5 per cent of the total peripheral area of the drum, using the diameter measured to the faces of the feet.
- Column 13, unit dry weights are for compacted soil at optimum moisture content for modified AASHTO compactive effort.

Figure 105. Characteristics of soils pertinent to roads and airfields.

Major Divisions (1) (2)		Letter (3)	Symbol Hatching (4)	Color (5)	Name (6)	Value for Embankments (7)	Permeability Cm Per Sec (8)	Compaction Characteristics (9)	Std AASHO Max Unit Dry Weight Lb Per Cu Ft (10)	Value for Foundations (11)	Requirements for Seepage Control (12)
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Very stable, pervious shells of dikes and dams	$k = 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	125-135	Good bearing value	Positive cutoff
		GP			Poorly-graded gravels or gravel-sand	Reasonably stable, pervious shells of dikes and dams	$k = 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	115-125	Good bearing value	Positive cutoff
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	120-135	Good bearing value	Toe trench to none
		GC			Clayey gravels, gravel-sand-clay mixtures	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	115-130	Good bearing value	None
	SAND AND SANDY SOILS	SW		Red	Well-graded sands or gravelly sands, little or no fines	Very stable, pervious sections, slope protection required	$k = 10^{-3}$	Good, tractor	110-130	Good bearing value	Upstream blanket and toe drainage or wells
		SP			Poorly-graded sands or gravelly sands, little or no fines	Reasonably stable, may be used in dike section with flat slopes	$k = 10^{-3}$	Good, tractor	100-120	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
		SM		Yellow	Silty sands, sand-silt mixtures	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	110-125	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
		SC			Clayey sands, sand-silt mixtures	Fairly stable, use for impervious core for flood control structures	$k = 10^{-6}$ to 10^{-8}	Fair, sheepsfoot roller, rubber tired	105-125	Good to poor bearing value	None
FINE GRAINED SOILS	SILTS AND CLAYS LL 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	95-120	Very poor, susceptible to liquefaction	Toe trench to none
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}	Fair to good, sheepsfoot roller, rubber tired	95-120	Good to poor bearing	None
		OL			Organic silts and organic silt-clays of low plasticity	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}	Fair to poor, sheepsfoot roller	80-100	Fair to poor bearing, may have excessive settlements	None
	SILTS AND CLAYS LL 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor stability, core of hydraulic fill dam, not desirable in rolled fill construction	$k = 10^{-4}$ to 10^{-6}	Poor to very poor, sheepsfoot roller	70-95	Poor bearing	None
		CH			Inorganic clays of high plasticity, fat clays	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}	Fair to poor, sheepsfoot roller	75-105	Fair to poor bearing	None
		OH			Organic clays of medium to high plasticity, organic silts	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}	Poor to very poor, sheepsfoot roller	65-100	Very poor bearing	None
	HIGHLY ORGANIC SOILS	Pt		Orange	Peat and other highly organic soils	Not used for construction		Compaction not practical		Remove from foundations	

- Notes:
1. Values in columns 7 and 11 are for guidance only. Design should be based on test results.
 2. In column 9, the equipment listed will usually produce the desired densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.
 3. Column 10, unit dry weights are for compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.

Figure 106. Characteristics of soils pertinent to embankments and foundations.

196. Nails and Spikes

a. *Types and uses.* See figure 107 for the sizes and uses of various types of nails.

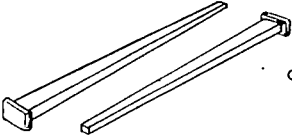
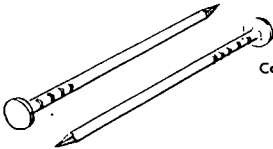
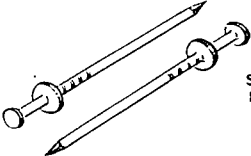
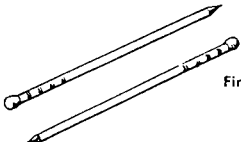
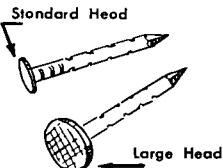
Type	Size	Use
 Cut Nail	2d to 60d	An old type no longer used except in 8d size for flooring and in various sizes for special purposes. Square point permits it to penetrate with less splitting than wire nails. Tapered shank permits drawing of floor joints much tighter than with wire nails.
 Common Nail	2d to 60d	Standard for concealed work, rough work, and most exposed exterior work. For work to be painted the head can be set and covered with putty. Better holding power than the finishing nail.
 Scaffold or Form Nail	1 3/4" to 4 1/2"	For temporary use in scaffolds and concrete forms. Double head facilitates withdrawal. Also used as a self-furring nail on exterior metal lath.
 Finishing Nail	2d to 20d	For wood trim and other interior work for paint or varnish finish. The head is set below the surface leaving a small hole to be puttied.
 Lath Nail	2d to 4d	For lathing; wood lath, gypsum lath, fiber lath, and interior metal lath.
 Barbed Roofing	3/4" to 2"	For the first felt layer of built-up roofing over wood sheathing.

Figure 107. Nails.

b. Wire-Nail Sizes, Wire Gages, and Number Per Pound.

Table 206. Wire-Nail Sizes, Wire Gages, and Number Per Pound

Size	Length (inches)	Common		Siding		Finishing		Flooring		Fence	
		Gage	No./lb.	Gage	No./lb.	Gage	No./lb.	Gage	No./lb.	Gage	No./lb.
2d.....	1	15	876	15½	1, 010	16½	1, 351				
3d.....	1¼	14	568	14½	635	15½	807				
4d.....	1½	12½	316	14	473	15	584				
5d.....	1¾	12½	271	14	406	15	500			10	142
6d.....	2	11½	181	12½	236	13	309	11	157	10	124
7d.....	2¼	11½	161	12½	210	13	238	11	139	9	92
8d.....	2½	10¼	106	11½	145	12½	189	10	99	9	82
9d.....	2¾	10¼	96	11½	132	12½	172	10	90	8	62
10d.....	3	9	69	10½	94	11½	121	9	69	7	50
12d.....	3¼	9	63			11½	113	8	54	6	40
16d.....	3½	8	49			11	90	7	43	5	30
20d.....	4	6	31			10	61	6	31		
30d.....	4½	5	24								
40d.....	5	4	18								
50d.....	5½	3	15								
60d.....	6	2	11								

Note 1. To avoid splitting, nail diameters should not exceed ¼ of the thickness of lumber to be nailed.

Note 2. Gages in above table are U.S. Steel Wire Gage. Fractional gages are:

Gage.....	10¼	10½	11½	12½	14½	15½
Diameter, inches....	0.1314	0.1278	0.1130	0.0985	0.0760	0.0673

c. Standard Barbed Roofing Nails.

Size and length..	$\frac{3}{4}$ "	$\frac{7}{8}$ "	1"	$1\frac{1}{8}$ "	$1\frac{1}{4}$ "	$1\frac{3}{8}$ "	$1\frac{1}{2}$ "	$1\frac{3}{4}$ "	2"
Gage.....	13	12	12	12	11	11	10	10	9
Number per pound.....	714	469	411	365	251	230	176	151	103

d. Standard Round Spikes, Flat Head, Diamond Point.

Size.....	10d	12d	16d	20d	30d	40d	50d	60d	7"	8"	9"	10"	12"
Length (inches)...	3	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	7	8	9	10	12
Gage.....	6	6	5	4	3	2	1	1	$\frac{5}{16}$ "	$\frac{3}{8}$ "	$\frac{3}{8}$ "	$\frac{3}{8}$ "	$\frac{3}{8}$ "
Number per pound.....	41	38	30	23	17	13	10	9	7	4	$3\frac{1}{2}$	3	$2\frac{1}{2}$

e. Nails and Spikes Stocked in Oversea Depots (Fed. Spec. FF-N-103 and FF-N-105) (SM 5-3). See table 207.

197. Wood Screws

The weight of flat-head bright wood screws, in pounds per gross, is given in table 208. The table also indicates the sizes manufactured. Sizes stocked in overseas depots are in italics.

198. Staples

a. Wire staples, fence steel, galvanized, are stocked in overseas depots in two sizes, $\frac{7}{8}$ -inch and $1\frac{1}{2}$ -inch, both of number 9 wire.

b. Cut-point staples (fig. 108) are furnished in five sizes for various cables and conductors.

199. Lag Screws

a. Dimensions. Diameters and threads per inch of lag screws are given in table 209; lengths of threaded portions of lag screws are given in table 210.

Table 207. Nails and Spikes Stocked in Oversea Depots

(Federal Specifications FF-N-103 and FF-N-105)

Description	Unit of issue	Expend-ability	Illustration No.	Remarks	
				Repair parts support code	Category of issue
NAIL, BOX, GENERAL PURPOSE, wire, steel, smooth shank, diamond point, flat head, Fed FF-N-105, box nail type:					
Cement coated finish:					
2d, 1 in. lg, 0.058 in. dia shank, 0.172 in. dia head.....	lb	X	-----	-----	5
3d, 1½ in. lg, 0.063 in. dia shank, 0.188 in. dia head.....	lb	X	-----	-----	5
4d, 1¾ in. lg, 0.067 in. dia shank, 0.203 in. dia head.....	lb	X	-----	-----	2, 5
5d, 1½ in. lg, 0.072 in. dia shank, 0.219 in. dia head.....	lb	X	-----	-----	5
6d, 1¾ in. lg, 0.086 in. dia shank, 0.250 in. dia head.....	lb	X	-----	-----	2, 5
7d, 2¼ in. lg, 0.086 in. dia shank, 0.250 in. dia head.....	lb	X	-----	-----	5
8d, 2¾ in. lg, 0.099 in. dia shank, 0.266 in. dia head.....	lb	X	-----	-----	2, 5
9d, 2¾ in. lg, 0.099 in. dia shank, 0.266 in. dia head.....	lb	X	-----	-----	5
10d, 2¾ in. lg, 0.113 in. dia shank, 0.297 in. dia head.....	lb	X	-----	-----	2, 5
Protective finish, not applicable:					
4d, 1½ in. lg, 0.080 in. dia shank, 0.219 in. dia head.....	lb	X	-----	-----	2, 5
5d, 1¾ in. lg, 0.080 in. dia shank, 0.219 in. dia head.....	lb	X	-----	-----	5
6d, 2 in. lg, 0.099 in. dia shank, 0.266 in. dia head.....	lb	X	-----	-----	5
7d, 2¼ in. lg, 0.099 in. dia shank, 0.266 in. dia head.....	lb	X	-----	-----	5
8d, 2½ in. lg, 0.113 in. dia shank, 0.297 in. dia head.....	lb	X	-----	-----	2, 5
10d, 3 in. lg, 0.128 in. dia shank, 0.313 in. dia head.....	lb	X	-----	-----	2, 5

NAIL, BOX, NAILING MACHINE, wire, steel, cement coated finish, Ref Dwg

Group 22, sections B, D, E, smooth shank, style 16, diamond point, style 7:

Flat countersunk head, style 18, Fed FF-N-105, cement coated countersunk head nail type:

3d, 1½ in. lg, 0.067 in. dia shank, 0.172 in. dia head.....	lb	X			5
4d, 1½ in. lg, 0.020 in. dia shank, 0.203 in. dia head.....	lb	X			5
5d, 1½ in. lg, 0.026 in. dia shank, 0.219 in. dia head.....	lb	X			5
6d, 1½ in. lg, 0.092 in. dia shank, 0.234 in. dia head.....	lb	X			5
8d, 2½ in. lg, 0.113 in. dia shank, 0.266 in. dia head.....	lb	X			5
10d, 2½ in. lg, 0.121 in. dia shank, 0.281 in. dia head.....	lb	X			5
12d, 3½ in. lg, 0.135 in. dia shank, 0.313 in. dia head.....	lb	X			5
20d, 3¾ in. lg, 0.177 in. dia shank, 0.375 in. dia head.....	lb	X			5
30d, 4¼ in. lg, 0.192 in. dia shank, 0.406 in. dia head.....	lb	X			5
40d, 4¾ in. lg, 0.207 in. dia shank, 0.438 in. dia head.....	lb	X			1, 5
60d, 5¼ in. lg, 0.244 in. dia shank, 0.500 in. dia head.....	lb	X			5

Flat head, style 14, Fed FF-N-105, cement coated standard, nail type:

2d, 1 in. lg, 0.063 in. dia shank, 0.172 in. dia head.....	lb	X			5
3d, 1½ in. lg, 0.067 in. dia shank, 0.188 in. dia head.....	lb	X			2, 5
4d, 1½ in. lg, 0.080 in. dia shank, 0.219 in. dia head.....	lb	X			2, 5
5d, 1½ in. lg, 0.086 in. dia shank, 0.234 in. dia head.....	lb	X			2, 5
6d, 1½ in. lg, 0.092 in. dia shank, 0.250 in. dia head.....	lb	X			2, 5
7d, 2½ in. lg, 0.039 in. dia shank, 0.266 in. dia head.....	lb	X			5
8d, 2½ in. lg, 0.113 in. dia shank, 0.281 in. dia head.....	lb	X			2, 5
10d, 2½ in. lg, 0.121 in. dia shank, 0.297 in. dia head.....	lb	X			2, 5

NAIL CASING, wire steel, Ref Dwg Group 22, sections B, D, E, smooth shank, style

18, diamond point, style 16, flat countersunk head, style 13, Fed FF-N-105:

4d, 1½ in. lg.....	lb	X			2
6d, 2 in. lg.....	lb	X			2
8d, 2½ in. lg.....	lb	X			2

NAIL, CLOUT, cut, steel, Ref Dwg Group 22, sections B, D, E, tapered shank, style

19, blunt point, style 2, flat head, style 14, Fed FF-N-103:

¾ in. lg.....	lb	X			1, 2
1 in. lg.....	lb	X			1, 2

Table 207. Nails and Spikes Stocked in Oversea Depots—Continued

(Federal Specifications FF-N-103 and FF-N-105)

Description	Unit of issue	Expend-ability	Illustration No.	Remarks	
				Repair parts support code	Category of issue
NAIL, COMMON, wire, steel, smooth shank, diamond point, flat head, Fed FF-N-105:					
2d, 1 in. lg-----	lb	X	-----	-----	1, 2, 5
3d, 1¼ in. lg-----	lb	X	-----	-----	2, 4
4d, 1½ in. lg-----	lb	X	-----	-----	1, 2, 4
5d, 1¾ in. lg-----	lb	X	-----	-----	5
6d, 2 in. lg-----	lb	X	-----	-----	1, 2, 4
7d, 2¼ in. lg-----	lb	X	-----	-----	5
8d, 2½ in. lg-----	lb	X	-----	-----	1, 2, 4
9d, 2¾ in. lg-----	lb	X	-----	-----	5
10d, 3 in. lg-----	lb	X	-----	-----	1, 2, 4, 8
12d, 3¼ in. lg-----	lb	X	-----	-----	1, 2, 4, 8
16d, 3½ in. lg-----	lb	X	-----	-----	1, 2, 4
20d, 4 in. lg-----	lb	X	-----	-----	1, 2, 4
30d, 4½ in. lg-----	lb	X	-----	-----	1, 2, 4
40d, 5 in. lg-----	lb	X	-----	-----	1, 2, 4, 8
50d, 5½ in. lg-----	lb	X	-----	-----	2, 4
60d, 6 in. lg-----	lb	X	-----	-----	1, 2, 4, 8
Zinc coated finish:					
4d, 1½ in. lg-----	lb	X	-----	-----	1, 2
20d, 4 in. lg-----	lb	X	-----	-----	1
NAIL, COMPOSITION ROOFING, wire, steel, zinc coated finish, Ref Dwg Group 22, sections B, D, E, barbed shank, style 1, diamond point, style 7, flat head, style 14, Fed FF-N-103, roofing nail type:					

$\frac{3}{8}$ in. lg.-----	lb	X			2, 4
1 in. lg.-----	lb	X			2, 4
NAIL, DOUBLE HEADED, wire, steel, Ref Dwg Group 22, sections B, D, E, smooth shank, style 16, diamond point, style 7, duplex head, style 11, Fed FF-N-105, duplex head nail type:					
8d, $2\frac{1}{4}$ in. lg. from under lower head to point, $\frac{1}{4}$ in. lg. between heads, 0.131 in. dia shank.	lb	X			2
10d, $2\frac{3}{4}$ in. lg. from under lower head to point, $\frac{3}{16}$ in. lg. between heads, 0.148 in. dia shank.	lb	X			2
16d, 3 in. lg. from under lower head to point, $\frac{3}{8}$ in. lg. between heads, 0.182 in. dia shank.	lb	X			2
NAIL, DRIVE SCREW, wire, steel, Ref Dwg Group 22, sections B, D, E, screw shank, style 11, needle point, style 9, oval head style 43, $1\frac{1}{4}$ in. lg, 0.177 in. dia. shank, Signode Co. or equal.	lb	X		5	
NAIL, FINISHING, wire, steel, Ref. Dwg. Group 22, sections B, D, E, smooth shank, style 11, needle point, style 9, oval head style 43, $1\frac{1}{4}$ in. lg, 0.177 in. dia. shank, Signode Co. or equal.					
NAIL, FINISHING, wire, steel, Ref. Dwg. Group 22, sections B, D, E, smooth shank, style 16, diamond point, style 7, brad head, style 2, Fed FF-N-105:					
3d, $1\frac{1}{4}$ in. lg.-----	lb	X			2
4d, $1\frac{1}{2}$ in. lg.-----	lb	X			1, 2
6d, 2 in. lg.-----	lb	X			1, 2
8d, $2\frac{1}{2}$ in. lg.-----	lb	X			2
10d, 3 in. lg.-----	lb	X			2
NAIL, FOUNDRY, wire, steel, protective finish not applicable, Ref. Dwg. Group 2 $\frac{1}{2}$, sections B, D, E, smooth shank, style 16, diamond point, style 7, flat head, style 14, 0.162 in. dia. shank, 0.500 in. dia. head, Fed FF-N-101:					
1 in. lg.-----	lb	X			1, 2
2 in. lg.-----	lb	X			1, 2
3 in. lg.-----	lb	X			1, 2

Table 208. *Sizes and Weights of Wood Screws*

Size	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	6	
0	0.024	0.040																			
1	.037	.060	0.07	0.09																	
2	.052	.085	.10	.12	0.13	0.15															
3	.070	.101	.13	.15	.17	.20	0.26	0.30													
4	.092	.13	.16	.19	.22	.26	.29	.37	0.44												
5		.16	.20	.25	.29	.33	.38	.48	.56	0.64	0.73										
6		.20	.25	.30	.36	.41	.46	.59	.68	.79	.90	1.10	1.13	1.25	1.35						
7		.24	.31	.37	.43	.50	.56	.72	.84	.96	1.10	1.23	1.37	1.53	1.64						
8		.29	.37	.44	.56	.59	.67	.85	.99	1.15	1.32	1.46	1.64	1.82	1.96	2.25	2.57				
9		.34	.44	.52	.61	.70	.79	.99	1.17	1.35	1.54	1.71	1.93	2.12	2.29	2.63	3.00				
10			.51	.60	.71	.81	.92	1.16	1.36	1.57	1.78	2.00	2.24	2.46	2.67	3.07	3.48				
11			.58	.69	.82	.94	1.07	1.34	1.56	1.80	2.04	2.32	2.59	2.85	3.09	3.53	4.01				
12			.66	.79	.93	1.07	1.21	1.52	1.78	2.07	2.35	2.64	2.94	3.25	3.52	4.01	4.57	5.14	5.80		
13				.90	1.05	1.21	1.37	1.72	2.01	2.34	2.67	2.97	3.33	3.67	3.97	4.53					
14					1.03	1.18	1.36	1.54	1.93	2.26	2.63	2.99	3.33	3.72	4.10	4.44	5.08	5.75	6.25	7.34	8.60
15					1.32	1.53	1.74	2.15	2.54	2.92	3.34	3.72	4.16	4.56	4.94	5.65					
16					1.47	1.71	1.92	2.39	2.82	3.25	3.73	4.14	4.62	5.06	5.98	6.28	7.10	8.09	9.04	10.70	
17							2.12	2.65	3.13	3.61	4.13	4.58	5.13	5.61	6.07	6.95					
18							2.34	2.95	3.45	4.00	4.53	5.05	5.65	6.18	6.70	7.68	8.67	9.89	11.10	12.90	
20								3.50	4.10	4.78	5.40	6.03	6.76	7.36	7.98	9.13	10.40	11.80	13.40	15.40	
22								4.13	4.86	5.60	6.35	7.04	7.90	8.55	9.35	10.70	12.20	13.80	15.50	18.30	
24								4.78	5.65	6.52	7.39	8.26	9.13	10.01	10.81	12.50	14.15	16.20	18.15	21.20	
26															12.50	14.40	16.25	18.60	20.80	24.40	
28																	18.40	21.25	23.75	27.70	
30																	21.00	24.30	27.30	31.80	

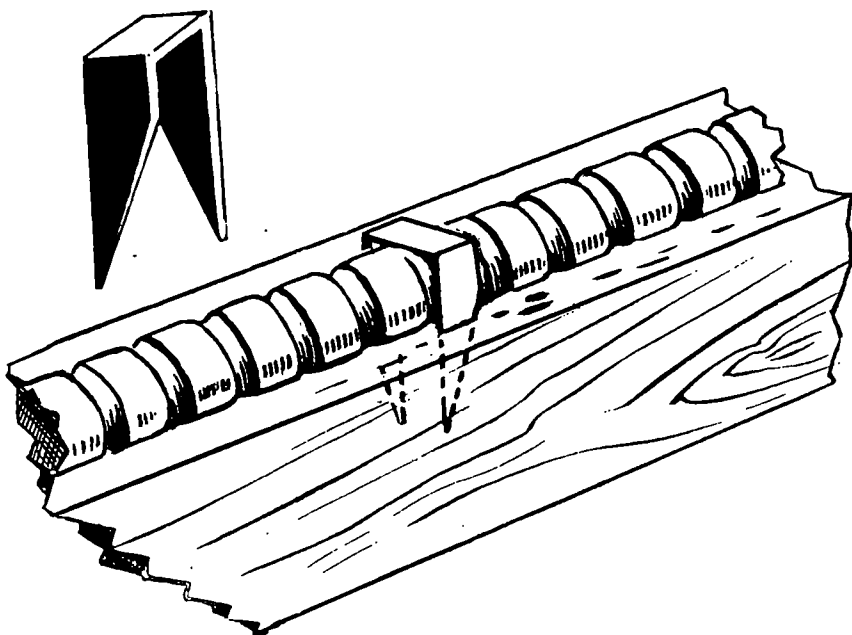


Figure 108. Cut-point staples.

Table 209. Diameters and Threads Per Inch of Lag Screws

	Lag screw diameters								
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Diameter at root of thread, inches.	0. 173	0. 227	0. 265	0. 328	0. 371	0. 471	0. 579	0. 683	0. 780
Diameter of pilot hole for threads, inches.	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
Threads per inch.	10	9	7	7	6	5	4½	4	3½

b. Sizes Stocked in Oversea Depots.

- (1) Standard lag screws, cone point: $\frac{1}{4}$ - by 1-inch, $\frac{3}{8}$ - by 4-inch, $\frac{1}{2}$ - by 2-inch, $\frac{1}{2}$ - by 4-inch, $\frac{5}{8}$ - by 4-inch, and $\frac{3}{4}$ - by 4-inch.
- (2) Gimlet point: black, $\frac{3}{8}$ - by 3-inch; galvanized $\frac{1}{2}$ - by 4½-inch.

Table 210. Lengths of Threaded Portions of Lag Screws

Lag screw lengths, inches ¹	Lag screw diameters								
	¼	⅜	½	⅝	¾	⅞	1	1 ¼	1 ½
2 and 2½-----	1½	1½	1½	1½	1½	1½	-----	-----	-----
2½ and 2¾-----	1½	1½	1½	1¾	1¾	1¾	-----	-----	-----
3 and 3½-----	2	2	2	2	2	2	2	2	2
4 and 4½-----	2½	2½	2½	2½	2½	2½	2½	2½	2½
5 and 5½-----	3	3	3	3	3	3	3	3	3
6 and 6½-----	3½	3½	3½	3½	3½	3½	3½	3½	3½
7 and 7½-----	4	4	4	4	4	4	4	4	4
8 and 8½-----	4½	4½	4½	4½	4½	4½	4½	4½	4½
9 and 9½-----	5	5	5	5	5	5	5	5	5
10-----	5¼	5¼	5¼	5¼	5¼	5¼	5¼	5¼	5¼
11-----	-----	-----	5½	5½	5½	5½	5½	5½	5½
12-----	-----	-----	6	6	6	6	6	6	6
13-----	-----	-----	-----	-----	6½	6½	6½	6½	6½
14-----	-----	-----	-----	-----	7	7	7	7	7
15-----	-----	-----	-----	-----	7½	7½	7½	7½	7½
16-----	-----	-----	-----	-----	8	8	8	8	8

¹ Measured from underside of head to point.

200. Bolts, Machine, American Standard Regular

Table 211. Bolt Sizes and Threads

Bolt (inches)	Number of threads per inch ¹	Diameter at root of thread (inches)	Area at root of thread (square inches)	Short diameter of square head (inches)	Short diameter of nut (square or hexagon) (inches)	Height of nut (inches)
¼-----	20	0. 185	0. 027	⅜	⅞	¼
⅜-----	16	. 294	. 068	⅝	¾	⅜
½-----	13	. 400	. 126	¾	1 ⅛	½
⅝-----	11	. 507	. 202	1 ⅛	1	⅝
¾-----	10	. 620	. 302	1 ⅝	1 ⅝	1 ⅛
⅞-----	9	. 731	. 419	1 ⅞	1 ⅞	¾
1-----	8	. 838	. 551	1½	1½	⅞
1 ⅛-----	7	. 939	. 693	1 11/16	1 11/16	1
1 ¼-----	7	1. 064	. 890	1 7/8	1 7/8	1 ⅛
1 ⅝-----	6	1. 158	1. 054	2 1/16	2 1/16	1 ¼
1 ¾-----	6	1. 283	1. 294	2 ¼	2 ¼	1 ⅝
1 ⅞-----	-----	-----	-----	2 7/16	2 7/16	1 ¾
1¾-----	5	1. 490	1. 744	2 ⅝	2 ⅝	1 ¾
1 7/8-----	-----	-----	-----	2 11/16	2 11/16	1 7/8
2-----	4½	1. 711	2. 300	3	3 ⅛	2
2 ¼-----	4½	1. 961	3. 031	3 ⅜	3 ½	2 ¼
2 ½-----	4	2. 175	3. 716	3 ¾	3 ¾	2 ½
2 ¾-----	4	2. 425	4. 619	4 ⅛	4 ¼	2 ¾
3-----	4	2. 675	5. 621	4 ½	4 ⅝	3

¹ American National Form screw threads.

201. Manila Rope

a. *Weight and Strength.* Table 212 shows the unit weights and breaking strengths of the most commonly used sizes of manila rope (natural color, three-strand, oil-treated).

b. *Sheave Diameters.* Within the range of sizes shown in table 212, sheave diameter should be not less than eight times the diameter of the rope.

Table 212. Manila Rope

Circumference (inches)	Feet per pound	Breaking strength (pounds)
¾-----	50. 0	600
1-----	34. 5	1, 000
1¼-----	24. 4	1, 359
1½-----	13. 3	2, 650
2-----	7. 5	4, 400
2¼-----	6. 0	5, 400
2½-----	5. 13	6, 500
2¾-----	4. 54	7, 700
3-----	3. 71	9, 000

202. Sand, Gravel, Crushed Rock

Tables 213 through 218 give data on sand, gravel, and crushed rock used as construction materials.

Table 213. Linear Feet of Spread of Gravel and Crushed Rock To Produce 1-Inch Thickness

Width, feet	Thickness		Linear feet of spread 1 cu. yd.
	Inches	Condition ¹	
10-----	1	{ Loose-----	32. 4
		{ Compacted-----	25. 9

¹ Ratio of loose thickness to compacted thickness assumed to be 1.25 to 1.

Example: Length of spread for 2½-cubic yard truckload of gravel to produce 4-inch compacted thickness 22 feet wide is:

$$L=25.9\times\frac{10}{22}\times2.5\times\frac{1}{4}=7.3\text{ feet.}$$

Table 214. Cubic Yards, Loose Measure, Gravel or Crushed Rock Required Per Linear Unit of Road to Produce 1-Inch Thickness

Width in feet	Condition ¹	Length of road section		
		100 ft.	100 yd.	1 mile
10-----	{ Loose-----	3. 09	9. 26	162. 9
	{ Compacted-----	3. 86	11. 57	203. 6

¹ Ratio of loose thickness to compacted thickness assumed to be 1.25 to 1.

Example: Quantity required for 4-inch compacted course
on 350 yards of road 22-feet wide is:

$$Q = 11.57 \times \frac{22}{10} \times \frac{4}{1} \times \frac{350}{100} = 356.4 \text{ cubic yards, loose measure.}$$

Table 215. Square Yards per Hundred Running Feet, per Hundred Yards, and Per Mile for Various Surface Widths

Width in feet	Number of square yards—		
	Per 100 ft.	Per 100 yd.	Per mile
9-----	100. 0	300. 0	5, 280
10-----	111. 1	333. 3	5, 867
12-----	133. 3	400. 0	7, 040
16-----	177. 8	533. 3	9, 387
18-----	200. 0	600. 0	10, 560
20-----	222. 2	666. 7	11, 734
22-----	244. 4	733. 3	12, 907

Table 216. Pounds of Aggregate Required per Square Yard for Various Thicknesses of Compacted Layers

Weight of 1 cu. yd. dry loose aggregate, pounds	Thickness of compacted layer ¹					
	½ in.	¾ in.	1 in.	2 in.	2½ in.	3 in.
2,100-----	37	56	74	149	186	223
2,200-----	38	58	77	154	199	231
2,300-----	40	60	80	164	205	246
2,400-----	41	61	82	164	205	246
2,500-----	42	63	84	169	211	253
2,600-----	43	65	87	173	217	260
2,700-----	44	67	89	178	222	267
2,800-----	45	68	91	182	227	273
2,900-----	47	70	93	186	233	279
3,000-----	47	71	95	190	237	285

¹ Compaction ratio assumed to be 1.25 to 1.

Table 217. Average Weights of Aggregates and Soils Per Cubic Yard

Description	Loose pounds	Compacted pounds
Earth.....	2, 100	2, 700
Coarse material macadam aggregate.....	2, 500	3, 100
Graded sand.....	2, 600	3, 300
Graded gravel or crushed rock.....	2, 800	3, 600

Table 218. Weight of Crushed Rock

Type of rock	Weight of crushed rock	
	Pounds per cubic foot	Tons per cubic yard
Trap rock.....	107	1. 45
Granite.....	97	1. 31
Limestone.....	100	1. 35
Shale.....	95	1. 28
Gravel.....	105	1. 41

Section VII. MASONRY

203. Stone Masonry

a. Ashlar. This is the best type of stone masonry and the type used for work requiring great strength and stability. It is characterized by carefully bonded and fitted stones set on level beds and laid with joints varying from $\frac{1}{8}$ to $\frac{1}{4}$ inch thick for architectural work and from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick for railroad masonry.

b. Squared-Stone Masonry. Usually constructed as broken-course work, this type is fitted less carefully than ashlar, more carefully than rubble. Well-built squared-stone masonry normally includes the highest types used in military construction.

c. Rubble. Rubble masonry is built with a minimum of dressing, with joints unevenly coursed, or in a completely irregular pattern. Stones are lapped for bond and many stones extend through a wall to bond it transversely. If built carefully, with all interstices completely filled with good cement mortar and bedded spalls, rubble masonry has ample strength and durability for ordinary structures.

204. Brick Masonry

a. Types of Brick.

- (1) Common brick, normally 8 by $3\frac{3}{4}$ by $2\frac{1}{8}$ inches are used in all brickwork unless other types are specifically mentioned. They are typically kiln-burned clay or clay-and-shale mix-

tures, but are also made of a sand-lime combination, steam cured, or of sand and portland cement, moist cured.

(2) *Paving brick.* Vitrified paving brick and paving blocks, very hard and durable, are used in any structure in which these qualities are required.

(3) Firebrick, laid in a thin grout of fire clay, are used in furnace linings and other refractory service.

b. Brick Quantities. In common brick masonry, about $6\frac{3}{4}$ brick are required per square foot of wall 1 brick in thickness; 20 brick per cubic foot of masonry.

c. Rate of Laying Brick. A skilled bricklayer can lay 1,200 or more brick per 8-hour day in straight walls 3 bricks or more in thickness; 200 to 600 brick in thinner walls or in work having many corners, angles, or openings. These maximum rates are not normally attained in peacetime construction in this country.

205. Hollow-Tile and Concrete-Block Masonry

These materials are used in lightweight walls and partitions to provide thicknesses necessary for stability or to provide stable backing for 4-inch brick facing. Usual sizes and types are as follows:

a. Hollow Tile.

(1) For backup and bearing-wall purposes, many sizes and types have been developed, typically to provide hollow-tile wall thicknesses of 8 inches and 12 inches. A common type is the 6-cell hollow tile 8 by 12 inches, weighing about 36 pounds. It can be used for walls of either 8- or 12-inch thickness.

(2) For partitions, 3-cell tile with 12- by 12-inch faces are made for 3-, 4-, and 6-inch wall thicknesses.

b. Concrete Blocks. These are typically 12 or 16 inches long, 8 inches high, and made for wall thicknesses of 4, 8, and 12 inches. Walls 12 inches thick are used for foundation walls for light structures, the 8-inch thickness for exterior walls above grade and for piers, and the 4-inch thickness for partitions.

206. Unit Weights

	<i>Weight in pounds per cubic foot</i>
Squared-stone masonry.....	150 to 170
Rubble-stone masonry.....	130 to 155
Brick masonry.....	125 to 140
Hollow-tile or concrete-block masonry.....	40 to 70

207. Mortar

For 1 cubic yard of 1:3 cement mortar with 10 percent of the cement replaced by lime putty, about 880 pounds of portland cement and 40 pounds of hydrated lime are added to 1 cubic yard of sand, damp and loose measure. More sand, up to a total of 2 cubic yards, is added if less strength is needed. For a 1-bag batch, the usual quantities are

94 pounds of cement, 5 pounds of hydrated lime, and 3 to 5 cubic feet of sand. The number of cubic yards of mortar per hundred square feet of wall of various materials are as follows:

	Wall thickness (inches)			
	4	8	12	18
Rubble stone.....				0.8
Common brick.....	0.3	0.7	1.2	
Hollow tile or concrete blocks.....	.14	.23	.36	

Section VIII. EXPLOSIVES

208. General

TM 9-1910 presents basic data on the subject. FM 5-25 summarizes the characteristics of explosives and their uses. TM 5-220 includes obstacle removing by explosives. TM 9-1946 describes demolition materials and their use. FM 5-34 gives explosives and demolition data for field use.

209. Weights of Explosives

Table 219 lists certain standard explosive charges with their net weights and package weights. For further details see SM 9-5-1375.

Table 219. *Weights of Certain Explosive Charges*

Item	Net weight	Package weight
Charge, demolition, block, M5A1....	2½ lbs.....	75 lbs (24 charges)
½ lb TNT.....	½ lb.....	63 lbs (100 charges)
1 lb TNT.....	1 lb.....	63.7 lbs (50 charges)
8 lbs TNT.....	8 lbs.....	84 lbs (8 charges)

210. Use of Mines, Bombs, and Shells for Demolition

a. General. Use of such charges is generally uneconomical, but may be necessary. Great care should be exercised, especially in the case of mines. "*Dud*" shells or bombs should never be used.

b. Mines. Table 220 shows the weights and explosive contents of certain American and foreign antitank mines or equivalent. British mines listed are obsolete but still in use. German mines listed are from World War II; considerable stocks exist in various European countries.

c. Explosive Content of General-Purpose Bombs. The explosive content of bombs is approximately half their total weight. When used for demolitions, they are most effective as cratering charges. Their

shape makes them inefficient for demolitions requiring close contact between the explosive and the material to be blown. Data are given in table 221.

d. Artillery Shells. Artillery shells are used for demolition only where a fragmentation effect is desired. Because of their low explosive content they are seldom used for other demolition purposes. The 105-mm. howitzer HE shell weighs 33 pounds, but contains only 5

Table 220. *Weights and Explosive Contents of Mines*

Type	Weight of mine (pounds)	Weight of explosive (pounds)
UNITED STATES:		
M-7 (limited standard) (metal)	4½	3¾
M-6 (limited standard) (metal)	20	12
M-15 (standard) (metal)	30	21
M-19 (standard) (plastic)	28	21
UNION OF SOVIET SOCIALIST REPUBLICS:		
TM-35 (metal)	11. 4	6. 1
TM-38 (metal)	11. 2	6. 1
TM-39 (metal)	11. 4	7. 9
TM-41 (metal)	11-12	8. 8
TM-44 (metal)	15. 4-17. 6	11
TMD-B (wood)	15-17	10. 3-12. 1
YAM-5 (wood)	13-15	11-12
YAM-10 (wood)	22-27	16-22
TMB-2 (cardboard)	15. 4	11
LMG Rocket Mine (AIT rocket)	22	7. 16
Dog Mine (canvas charge case)	29-30	26. 4
(All above mines are "standard" items.)		
COMMUNIST CHINA:		
Chinese Mine No. 8 (limited use) (metal)	12	5
Chinese Mine No. 4 (standard) (metal)	16	12
GREAT BRITAIN:		
GS A/T Mark V (metal)	8. 75	4. 5
GS A/T Mark V HC (metal)	8. 75	8. 25
GS A/T Mark VC (metal)	8. 75	4. 5
FRANCE:		
M-1936 (metal)	14. 5	5. 75
M-1935 (metal)	27	3. 25
M-1947 (undetectable)	24. 3	13. 2
M-1948 (plate charge)	27. 5	16. 5
M-1951 (probe proof)	12. 5-17. 5	11-16
M-1951 (undetectable)	16-20	-----
GERMANY:		
Tellermine 29 (metal)	13	10
Tellermine 35 & 35 steel (metal)	19	11
Tellermine 42 (metal)	19	11
Tellermine 43 (metal)	18	12
Topfmine A (bituminous coal waste case)	21. 25	13
Topfmine B & C (bituminous coal waste case) ..	21. 25	13

Table 221. *Weights and Explosive Contents of Mines*

Bomb	Total weight (pounds)	Explosive weight (pounds)
100-pound GP, AN—M30-----	115	57
250-pound GP, AN—M57-----	260	129
300-pound GP, M31-----	280	144
500-pound GP, AN—M43-----	525	267
1,000-pound GP, AN—M44-----	990	558
2,000-pound GP, AN—M34-----	2, 100	1, 117

pounds of explosive. The 155-mm. howitzer HE shell contains but 15 pounds. Standard firing devices are adaptable only by using expedient methods for attachment to the shells.

211. Magazine Location

a. Accessibility, safety, dryness, and good drainage determine the magazine location. An isolated ravine is a good location. When single magazines are not isolated, or where magazines are built in groups, each magazine should be surrounded with breastworks or baffle walls to minimize damage to adjacent structures in case of an explosion, and to protect magazines from bomb and shell fragments.

b. The Ordnance Department has established quantity-distance tables, which furnish a correlation between the amount and kind of explosives in a magazine and the minimum distances of the magazine from various types of installation.

- (1) *Nature of explosive.* Explosives and allied substances handled by the Ordnance Corps are divided into thirteen classes, numbered classes 1, 2, 2a, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12.
- (2) *Distance categories.* Six categories are considered:
 - (a) *Inhabited building distance.*
 - (b) *Public railway distance.*
 - (c) *Public highway distance.*
 - (d) *Intraline distance,* defined as the minimum distance between any two buildings within one operating line.
 - (e) *Magazine distance,* defined as the minimum distance between any two storage magazines.
 - (f) *Missile distance,* identified as inhabited building distance for ammunition in classes 3, 4, 5, and 7.
- (3) *Quantity-distance tables.* For each class of explosives there is a quantity-distance table showing, for various amounts of stored explosive, what are the minimum distances of the several categories.
- (4) *Typical quantity-distance table.* Table 222 is the quantity-distance table for class 2 explosives, a common category.

Class 2 includes certain types of solid propellant (smokeless powder), chemical ammunition, military pyrotechnics, and some other items. The table applies for materials packed in approved storage containers, and/or cartridge cases; for smokeless powder in bulk, the minimum distances are higher. The table is in general typical of the various quantity-distance tables; but some classes of explosives—for example, class 8, which includes blasting caps, detonators, percussion elements, and electric primers—require considerably higher minimum distances.

Table 222. Quantity-Distance Table for Class 2 Materials

(Materials packed in approved storage containers and/or cartridge cases)

Quantity		Distance in feet			
Pounds (over)	Pounds (not over)	Inhabited building distance	Public railway distance	Public highway distance	Magazine and intra-line distance
100.....	1, 000	75	75	75	50
1,000.....	5, 000	115	115	115	75
5,000.....	10, 000	150	150	150	100
10,000.....	20, 000	190	190	190	125
20,000.....	30, 000	215	215	215	145
30,000.....	40, 000	235	235	235	155
40,000.....	50, 000	250	250	250	165
50,000.....	60, 000	260	260	260	175
60,000.....	70, 000	270	270	270	185
70,000.....	80, 000	280	280	280	190
80,000.....	90, 000	295	295	295	195
90,000.....	100, 000	300	300	300	200
100,000.....	200, 000	375	375	375	250
200,000.....	300, 000	450	450	450	300
300,000.....	400, 000	525	525	525	350
400,000.....	500, 000	600	600	600	400

CHAPTER 11

MISCELLANEOUS DATA

Section I. MATHEMATICAL DATA

212. Lengths, Areas, and Volumes

a. Legend.

A =area

a =altitude

b =length of base

c =hypotenuse

C =circumference

V =volume

r =radius

D =diameter

π =3.1416

l =length of arc

k =length of chord

b. Formulas.

(1) *Any triangle.* $A = \frac{1}{2}ab$

(2) *Right triangle.* $a = \sqrt{c^2 - b^2}$

$$b = \sqrt{c^2 - a^2}$$

$$c = \sqrt{a^2 + b^2}$$

(3) *Circle.* $A = \pi r^2$

$$A = 0.7854 D^2 \quad C = \pi D$$

(4) *Segment of circle.*

$$A = \frac{1}{2}[r(l - k) + ak]$$

$$l = \frac{\pi r}{180} (\text{angle in degrees})$$

$$k = 2\sqrt{2ar - a^2}$$

(5) *Sector of circle.*

$$A = \frac{rl}{2} = \frac{\pi r^2}{360} (\text{angle in degrees})$$

(6) *Regular polygons.* The area of any regular polygon (all sides equal; all angles equal) is equal to the product of the square of the length of one side and the factors shown in table 223.

Example: Area of regular octagon having 6-inch sides is $6 \times 6 \times 4.828$ or 173.81 square inches.

(7) *Rectangle and parallelogram.*

$$A = ab$$

Table 223. Polygon Factors

Number of sides	Factor	Number of sides	Factor
3-----	0. 433	8-----	4. 828
4-----	1. 000	9-----	6. 182
5-----	1. 720	10-----	7. 694
6-----	2. 598	11-----	9. 366
7-----	3. 634	12-----	11. 196

(8) *Trapezoid.*

$$A = \frac{1}{2}a(b_1 + b_2)$$

(9) *Irregular figures.* Measure widths at offsets regularly spaced along any straight line, and apply one of the following:

(a) *Trapezoidal rule.* $A = \frac{1}{2}$ interval between offsets X (sum of two end widths plus twice the sum of the intermediate widths).

(b) *Simpson's rule.* (Assumes lateral boundaries are parabolic curves.) $A = \frac{1}{3}$ interval between offsets X [sum of two end widths plus twice the sum of the odd widths except first and last (3d, 5th, 7th, etc.) plus 4 times the sum of the even widths (2d, 4th, 6th, etc.)]. (Note: The rule requires an odd number of widths. If there is an even number, compute separately the area of a trapezoid at one end.)

(10) *Cube.*

$$V = b^3$$

(11) *Rectangular parallelepiped.*

$$V = ab_1b_2$$

(12) *Prism or cylinder.*

$$V = aX \text{ (area of base)}$$

(13) *Pyramid or cone.*

$$V = \frac{1}{3}aX \text{ (area of base)}$$

(14) *Sphere.*

$$V = \frac{4}{3}\pi r^3 = \frac{\pi D^3}{6}$$

$$A = 4\pi r^2$$

(15) *Prismoidal section.*

$$V = \frac{1}{6} \text{ length } X \text{ (sum of end areas plus 4 times midsection area)}$$

213. Numerical Constants Containing π

Table 224. Numerical Constants Containing π

$$\pi = 3.14159\ 26536$$

$$\log_{10}\pi = 0.49714\ 98727$$

$$10_{\text{ge}}\pi = 1.14472\ 98858$$

	No.	Logarithm		No.	Logarithm
π -----	3. 1415 927	0. 4971 499	π^2 -----	9. 8696 044	0. 9942 997
2π -----	6. 2831 853	0. 7981 799	$2\pi^2$ -----	19. 7392 088	1. 2953 297
3π -----	9. 4247 780	0. 9742 711	$4\pi^2$ -----	39. 4784 176	1. 5963 597
4π -----	12. 5663 706	1. 0992 099	$1/\pi^2$ -----	0. 1013 212	9. 0057 003-10
8π -----	25. 1327 412	1. 4002 399	$1/(2\pi^2)$ -----	0. 0506 606	8. 7046 703-10
$\pi/2$ -----	1. 5707 963	0. 1961 199	$1/(4\pi^2)$ -----	0. 0253 303	8. 4036 403-10
$\pi/3$ -----	1. 0471 976	0. 0200 286	$\sqrt{\pi}$ -----	1. 7724 539	0. 2485 749
$\pi/4$ -----	0. 7853. 982	9. 8950 899-10	$\sqrt{\pi/4}$ or -----	0. 8862 269	9. 9475 449-10
$\pi/6$ -----	0. 5235 988	9. 7189 986-10	$\sqrt{\pi/2}$ -----		
$\pi/8$ -----	0. 3926 991	9. 5940 599-10	$\sqrt{\pi/4}$ -----	0. 4431. 135	9. 6465 149-10
$2\pi/3$ -----	2. 0943 951	0. 3210 586	$\sqrt{\pi 1/2}$ -----	1. 2533 141	0. 0980 599
$4\pi/3$ -----	4. 1887 902	0. 6220 886	$\sqrt{2/\pi}$ -----	0. 7978. 846	9. 9019 401-10
$1/\pi$ -----	0. 3183 099	9. 5028 501-10	π^3 -----	31. 0062 767	1. 4914 496
$2/\pi$ -----	0. 6366 198	9. 8038 801-10	$\sqrt[3]{\pi}$ -----	1. 4645 919	0. 1657 166
$4/\pi$ -----	1. 2732 395	0. 1049 101	$1/\sqrt[3]{\pi}$ -----	0. 6827 841	9. 8342 834-10
$1/(2\pi)$ -----	0. 1591 549	9. 2018 201-10	$\sqrt[3]{\pi/2}$ -----	2. 1450 294	0. 3314 332
$1/(4\pi)$ -----	0. 0795 775	8. 9007 901-10	$1/\sqrt{\pi}$ -----	0. 5641 896	9. 7514 251-10
$1/(6\pi)$ -----	0. 0530 516	8. 7246 989-10	$2/\sqrt{\pi}$ or -----	1. 1283 792	0. 0524 551
$1/(8\pi)$ -----	0. 0397 887	8. 5997 601-10	$\sqrt{4/\pi}$ -----		
$\pi/90$ -----	0. 0349 066	8. 5429 075-10			
$\pi/180$ -----	0. 0261 799	8. 4179 679-10			
$\pi/270$ -----	0. 0174 533	8. 2418 776-10			
$\pi/360$ -----	0. 0087 266	7. 9408 451-10			

214. Algebraic Formulas

a. Factors and Expansions.

$$(a+b)^2 = a^2 \pm 2ab + b^2$$

$$(a+b)^3 = a^3 \pm 3a^2b + 3ab^2 + b^3$$

$$(a+b)^4 = a^4 \pm 4a^3b + 6a^2b^2 \pm 4ab^3 + b^4$$

$$a^2 - b^2 = (a-b)(a+b)$$

$$a^2 + b^2 = (a+b\sqrt{-1})(a-b\sqrt{-1})$$

$$a^3 - b^3 = (a-b)(a^2 + ab + b^2)$$

$$a^3 + b^3 = (a+b)(a^2 - ab + b^2)$$

$$a^4 + b^4 = (a^2 + ab\sqrt{2} + b^2)(a^2 - ab\sqrt{2} + b^2)$$

$$a^n - b^n = (a-b)(a^{n-1} + a^{n-2}b + \dots + b^{n-1}), \text{ for odd values of } n.$$

$$a^n - b^n = (a+b)(a^{n-1} - a^{n-2}b + \dots - b^{n-1}), \text{ for even values of } n.$$

b. *Binomial Theorem.* The expansion of $(a+b)^n$, where n is a positive integer is

$$\begin{aligned} (a+b)^n = & a^n + na^{n-1}b + \frac{n(n-1)}{2!} a^{n-2}b^2 \\ & + \frac{n(n-1)(n-2)}{3!} a^{n-3}b^3 + \dots \\ & + \frac{n(n-1)(n-2)\dots(n-r+2)}{(r-1)!} a^{n-4+1}b^{r-1} + \dots + b^n. \end{aligned}$$

c. *Quadratic Equation.* The roots of any quadratic equation when reduced to the form $ax^2 + bx + c = 0$ are

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

If $(b^2 - 4ac)$ is positive, the roots are real and unequal.

If $(b^2 - 4ac)$ is zero, the roots are real and equal.

If $(b^2 - 4ac)$ is negative, the roots are imaginary and unequal.

If $(b^2 - 4ac)$ is a perfect square, the roots are rational and unequal.

d. Powers and Roots.

$$a^x \cdot a^y = a^{(x+y)}$$

$$a^0 = 1 \text{ (if } a \neq 0)$$

$$(ab)^x = a^x b^x$$

$$\frac{a^x}{a^y} = a^{(x-y)}$$

$$a^{-x} = \frac{1}{a^x}$$

$$\left(\frac{a}{b}\right)^x = \frac{a^x}{b^x}$$

$$(a^x)^y = a^{xy}$$

$$\frac{1}{a^x} = x\sqrt{x}a$$

$$x\sqrt{ab} = x\sqrt{a} x\sqrt{b}$$

$$x\sqrt{y}\sqrt{a} = xy\sqrt{a}$$

$$a^{\frac{x}{y}} = y\sqrt{y}a^x$$

$$x\sqrt{\frac{a}{b}} = \frac{x\sqrt{a}}{x\sqrt{b}}$$

e. Proportion.

$$\text{If } \frac{a}{b} = \frac{c}{d}$$

$$\text{then } \frac{a+b}{b} = \frac{c+d}{d}, \frac{a-b}{b} = \frac{c-d}{d}, \frac{a-b}{a+b} = \frac{c-d}{c+d}$$

f. Logarithms.

If $a^b = x$,
then $\log_a x = b$, by definition.

For change of base, $\log_a x = \frac{\log_c x}{\log_c a}$

To any base, $\log MN = \log M + \log N$
 $\log M^A = A \log M$

$\log \frac{M}{N} = \log MN^{-1} = \log M - \log N$

$\log n\sqrt[n]{M} = \log M^{\frac{1}{n}} = \frac{1}{n} \log M$

g. Sums of Numbers.

The sum of the first n numbers,

$$\sum(n) = 1 + 2 + 3 + 4 + 5 + \dots + n = \frac{n(n+1)}{2}$$

The sum of the squares of the first n numbers,

$$\sum(n^2) = 1^2 + 2^2 + 3^2 + 4^2 + 5^2 + \dots + n^2 = \frac{n(n+1)(2n+1)}{6}$$

The sum of the cubes of the first n numbers,

$$\sum(n^3) = 1^3 + 2^3 + 3^3 + 4^3 + 5^3 + \dots + n^3 = \frac{n^2(n+1)^2}{4}$$

h. Arithmetical Progression. If a is the first term; l , the last term; d , the common difference; n , the number of terms; and s , the sum of n terms, then

$$l = a + (n-1)d \quad s = \frac{n}{2}(a+l) \quad s = \frac{n}{2}[2a + (n-1)d]$$

i. Geometrical Progression. If a is the first term; l , the last term; r , the common ratio; n , the number of terms; and s , the sum of n terms, then

$$l = ar^{n-1} \quad s = a \frac{(l-r^n)}{l-r}$$

$$s = a \frac{(r^n-1)}{r-1} \quad s = \frac{lr-a}{r-l}$$

If n becomes infinite and r less than unity: $-s = \frac{a}{l-r}$

j. Factorials. The symbol n' , call " n factorial", represents the product of the first n positive integers.

$$n' = 1.2.3 \dots n.$$

$0' = 1$, by definition.

$$n' = e^{-n} n^n \sqrt{2\pi n}, \text{ approximately.}$$

k. Permutations. If P denotes the number of permutations of n things taken r at a time, then

$$P = n(n-1)(n-2) \dots (n-r+1)$$

l. Combinations. If C denotes the number of combinations of n things taken r at a time, then

$$C = \frac{n(n-1)(n-2) \dots (n-r+1)}{r!}$$

$$C = \frac{n!}{r!(n-r)!}$$

Section II. PHYSICAL DATA

215. Equivalents of Measure

Equivalent lengths, areas, cubes, weights, pressures, densities, velocities, work measurements, and U.S. weight equivalents are given in tables 225-233. Conversion scales for temperatures, lengths, and gallons are shown in figure 109.

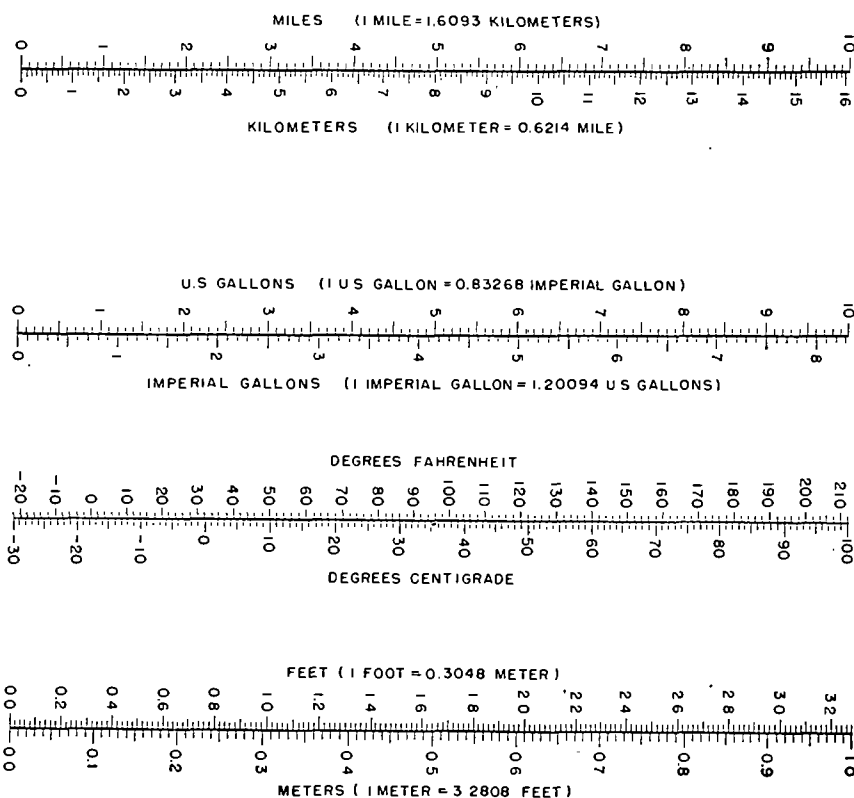


Figure 109. Conversion scales.

Table 225. Lengths

Meters,* m	Inches, in.	Feet, ft.	Yard, yd.	Rods, r.	Chains, ch.	Miles, U.S.		Kilometers, km
						Statute	Nautical	
1	39.37	3.28083	1.09361	0.19884	0.04971	0. ³ 6214	0. ³ 5396	0.001
.02540	1	.08333	.02778	. ² 5051	. ² 1263	. ⁴ 1578	. ⁴ 1371	. ⁴ 2540
.30480	12	1	.33333	.06061	.01515	. ³ 1894	. ³ 1645	. ³ 048
.91440	36	3	1	.18182	.04545	. ³ 5682	. ³ 4934	. ³ 9144
5.02921	198	16.5	5.5	1	.25	. ² 3125	. ² 2714	. ² 5029
20.1168	792	66	22	4	1	.01250	.01085	.02012
1609.35	63360	5280	1760	320	80	1	.86839	1.60935
1853.25	72962.5	6080.20	2026.73	368.497	92.1243	1.15155	1	1.85325
1000	39370	3280.83	1093.61	198.838	49.7096	.62137	.53959	1

* 1 meter (m)=10 decimeters (dm)=100 centimeters (cm)=1,000 millimeters (mm).

Note. Notations $\overset{2}{0}$, $\overset{3}{0}$, $\overset{4}{0}$, etc., indicate that the $\overset{2}{0}$, $\overset{3}{0}$, $\overset{4}{0}$, etc., are to be replaced by 2, 3, 4, etc., ciphers.

Example: 1 meter=0.³6214=0.0006214 statute miles.

Table 226. Areas

Sq. meters, sq. m	Sq. inches, sq. in.	Sq. feet, sq. ft.	Sq. yards, sq. yd.	Sq. rods, sq. r.	Acres, A	Hectares, ha.	Sq. miles, Statute	Sq. kilo- meters, sq. km
1	1550.00	10.7639	1.19599	0.03954	0. ³ 2471	0.0001	0. ⁶ 3861	0. ⁵ 1
. ³ 6452	1	. ² 6944	. ³ 7716	. ⁶ 2551	. ⁶ 1594	. ⁷ 6452	. ⁸ 2491	. ⁸ 6452
.09290	144	1	.11111	. ³ 3673	. ⁴ 2296	. ⁵ 9290	. ⁷ 3587	. ⁷ 9290
.83613	1296	9	1	.03306	. ³ 2066	. ⁴ 8361	. ⁶ 3228	. ⁶ 8361
25.2930	39204	272.25	30.25	1	.00625	. ³ 2529	. ⁵ 9766	. ⁴ 2529
4046.87	6272640	43560	4840	160	1	.40469	. ² 1563	. ² 4047
10000	15499969	107639	11959.9	395.366	2.47104	1	. ³ 861	.01
2589999	-----	27878400	3097600	102400	640	259.000	1	2.59000
1000000	-----	10763867	1195985	39536.6	247.104	100	.38610	1

Table 227. *Cubic Measures*¹

Cubic Decimeters, dm or Liters	Cubic Inches, cu. in.	Cubic Feet, cu. ft.	Cubic Yards, cu. yd.	U.S. Quarts		U.S. Gallons		U.S. Bushels, bu.
				Liquid, l. qt.	Dry d. qt.	Liquid, l. gal.	Dry, d. gal.	
1	61.0234	0.03531	0. ² ₀ 1308	1.05668	0.90808	0.26417	0.22702	0.02838
.01639	1	. ³ ₀ 5787	. ⁴ ₀ 2143	.01732	.01488	. ² ₀ 4329	. ³ ₀ 720	. ² ₀ 4650
28.3170	1728	1	.03704	29.9221	25.7140	7.48055	6.42851	.80356
764.559	46656	27	1	807.896	694.279	201.974	173.570	21.6962
.94636	57.75	.03342	. ² ₀ 1238	1	.85937	.25	.21484	.02686
1.10123	67.2006	.03889	. ² ₀ 1440	1.16365	1	.29091	.25	.03125
3.78543	231	.13368	. ² ₀ 4951	4	3.43747	1	.85937	.10742
4.40492	268.803	.15556	. ² ₀ 5761	4.65460	4	1.16365	1	.125
35.2393	2150.42	1.24446	.04609	37.2368	32	9.30920	8	1

¹ See also par. 82.

U.S. dry measure: 1 bushel=4 pecks=8 gallons=32 quarts=64 pints.

U.S. liquid measure: 1 gallon=4 quarts=8 pints=32 gills=128 fluid ounces. 1 U.S. gallon=0.83268 Imperial gallon.

Table 228. *Weights*

Kilograms, kg	Grains, gr.	Ounces		Pounds		Tons		
		Troy, oz. t.	Avoir., oz. av.	Troy, lb. t.	Avoir., lb. av.	Net (short), 2000 lbs.	Gross, (long), 2240 lbs.	Metric 1000 kg
1	15432.4	32.1507	35.2740	2.67923	2.20462	0. ² ₀ 1102	0. ³ ₀ 9842	0.001
. ⁴ ₀ 6480	1	. ² ₀ 2083	. ³ ₀ 2286	. ³ ₀ 1736	. ³ ₀ 1429	. ⁷ ₀ 7143	. ⁷ ₀ 6378	. ⁷ ₀ 6480
.03110	480	1	1.09714	.08333	.06857	. ⁴ ₀ 3429	. ⁴ ₀ 3061	. ⁴ ₀ 3110
.02385	437.5	.91146	1	.07595	.06250	. ⁴ ₀ 3125	. ⁴ ₀ 2790	. ⁴ ₀ 2835
.37324	5760	12	13.1657	1	.82286	. ³ ₀ 4114	. ³ ₀ 3674	. ³ ₀ 3732
.45359	7000	14.5833	16	1.21528	1	.00050	. ³ ₀ 4464	. ³ ₀ 4536
907.185	14000000	29166.7	32000	2430.56	2000	1	.89286	.90719
1016.05	15680000	32666.7	35840	2722.22	2240	1.12	1	1.01605
1000	15432356	32150.7	35274.0	2679.23	2204.62	1.10231	.98421	1

1 long hundredweight (cwt.) = 1/20 long ton = 4 quarters = 8 stone = 112 lbs. = 50.8024 kg.

Table 229. Pressures

Kilograms per sq. centimeter, kg/cm ²	Pounds per sq. inch, lb./in. ²	Pounds per sq. foot, lb./ft. ²	Net tons, (2000 lbs.), per sq. foot	Atmospheres, Standard, 760 mm	Columns of mercury, (Hg), 13.59593 Sp. G.		Columns of water, max. density 4° C.	
					Millimeters	Inches	Meters	Feet
1	14.2234	2048.17	1.02408	0.96778	735.514	28.9572	10	32.8083
.07031	1	144	.07200	.06804	51.7116	2.03588	.70307	2.30665
.34882	.6944	1	.00050	.04725	.35911	.01414	.04882	.01602
.97648	13.8889	2000	1	.94502	718.216	28.2762	9.76482	32.0367
1.03329	14.6969	2116.35	1.05818	1	760	29.9212	10.3329	33.9006
.21360	.01934	2.78468	1.21392	.21316	1	.03937	.01360	.04461
.03453	.49119	70.7310	.03537	.03342	25.4001	1	.34534	1.13299
.10	1.42234	204.817	.10241	.09678	73.5514	2.89572	1	3.28083
.03048	.43353	62.4283	.03121	.02950	22.4185	.88262	.30480	1

Table 230. Densities

Grams per cu. centimeter g/cm ³	Pounds per cu. inch lb./in. ³	Pounds per cu. foot lb./ft. ³	Pounds per cu. yard lb./yd. ³	Kilograms per cu. meter kg/m ³	Pounds per bushel, U.S.	Pounds per gallon, dry U.S.	Pounds per gallon, liquid, U.S.	Kilograms per hectoliter kg/hl
1	0.03613	62.4283	1685.56	1000	77.6893	9.71116	8.34545	100
27.6797	1	1728	46656	27679.7	2150.42	268.803	231	2767.97
.01602	.35787	1	27	16.0184	1.24446	.15556	.13368	1.60184
.35933	.2143	.03704	1	.59327	.04609	.05762	.24951	.05933
.001	.3613	.06243	1.68556	1	.07769	.09711	.08345	.10
.01287	.34650	.80356	21.6962	12.8718	1	.125	.10742	1.28718
1.0297	.3720	6.42851	173.570	102.974	8	1	.85937	10.2974
.11983	.34329	7.48052	201.974	119.826	9.30920	1.16365	1	11.9826
.01	.3613	.62428	16.8557	10	.77689	.09711	.08345	1

Table 231. Velocities

Meters per second (m./sec.)	Feet per second (ft./sec.)	Miles per hour (m.p.h.)	Nautical miles per hour (knots) (U.S.)	Kilometers per hour (km/hr.)
1	3. 28083	2. 23693	1. 94254	3. 6
. 30480	1	. 68182	. 59209	1. 09728
. 44704	1. 46667	1	. 86839	1. 60935
. 51479	1. 68894	1. 15155	1	1. 85325
. 27778	. 91134	. 62137	. 53959	1

Table 232. Work Measurements

Kilogram-meters per second, kg-m/sec.	Foot-pounds per second, ft.-lbs./sec.	Horsepower		Poncelet, 100 kg-m/sec.	Kilowatt, kw.	Watts, 10 ergs/sec.	Thermal units per Sec.	
		U.S., 550 ft.-lbs./sec.	Metric, 75 kg-m/sec.				B.T.U., B.T.U./sec.	Calorie, kg-cal/sec.
1	7.23300	0.01315	0.01333	0.01	0. ² 9806	9.80597	0. ² 9296	0. ² 2342
.13826	1	² .01818	² .01843	² .01383	² .01356	1.35573	² .01285	³ .03237
76.0404	550	1	1.01387	.76040	.74565	745.650	.70865	.17812
75	542.475	.98632	1	.75	.73545	735.448	.69718	.17569
100	723.300	1.31509	1.33333	1	.98060	980.597	.92957	.23425
101.979	737.612	1.34111	1.35972	1.01979	1	1000	.94796	.23888
.10198	.73761	² .01341	² .01360	² .01020	.001	1	³ .09480	³ .02389
107.577	778.104	1.41474	1.43436	1.07577	1.05490	1054.90	1	.25200
426.900	3087.77	5.61412	5.69200	4.26900	4.18617	4186.17	3.96832	1

Table 233. United States Weight Equivalents

Avoirdupois pounds	Kilograms	Short tons	Long tons
1-----	0. 453 59	0. 0005	0. 000 446 43
2-----	. 907 18	. 0010	. 000 892 86
3-----	1. 360 78	. 0015	. 001 339 29
4-----	1. 814 37	. 0020	. 001 785 71
5-----	2. 267 96	. 0025	. 002 232 14
6-----	2. 721 55	. 0030	. 002 678 57
7-----	3. 175 15	. 0035	. 003 125 00
8-----	3. 628 74	. 0040	. 003 571 43
9-----	4. 082 33	. 0045	. 004 017 86
2. 204 62-----	1	. 001 102 31	. 000 984 21
4. 409 24-----	2	. 002 204 62	. 001 968 41
6. 613 87-----	3	. 003 306 93	. 002 952 62
8. 818 49-----	4	. 004 409 24	. 003 936 83
11. 023 11-----	5	. 005 511 56	. 004 921 03
13. 227 73-----	6	. 006 613 87	. 005 905 24
15. 432 36-----	7	. 007 716 18	. 006 889 44
17. 636 98-----	8	. 008 818 49	. 007 873 65
19. 841 60-----	9	. 009 920 80	. 008 857 86

Table 233. United States Weight Equivalents—Continued

Avoirdupois pounds	Kilograms	Short tons	Long tons
2000-----	907. 18	1	0. 892 86
4000-----	1814. 37	2	1. 785 71
6000-----	2721. 55	3	2. 678 57
8000-----	3628. 74	4	3. 571 43
10 000-----	4535. 92	5	4. 464 29
12 000-----	5443. 11	6	5. 357 14
14 000-----	6350. 29	7	6. 250 00
16 000-----	7257. 48	8	7. 142 86
18 000-----	8164. 66	9	8. 035 71
2240-----	1016. 05	1. 12	1
4480-----	2032. 09	2. 24	2
6720-----	3048. 14	3. 36	3
8960-----	4064. 19	4. 48	4
11 200-----	5080. 24	5. 60	5
13 440-----	6096. 28	6. 72	6
15 680-----	7112. 32	7. 84	7
17 920-----	8128. 38	8. 96	8
20 160-----	9144. 42	10. 08	9

216. Inches to Decimals of a Foot

Table 234. Inches to Decimals of a Foot

	0	1	2	3	4	5	6	7	8	9	10	11
0-----	0	0.0833	0.1667	0.2500	0.3333	0.4167	0.5000	0.5833	0.6667	0.7500	0.8333	0.9167
1/16-----	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1/8-----	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
3/16-----	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1/4-----	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5/16-----	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3/8-----	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
7/16-----	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1/2-----	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9/16-----	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5/8-----	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11/16-----	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3/4-----	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13/16-----	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7/8-----	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
15/16-----	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948

217. British Weight Markings

If British weights are marked with four separate figures in one line, the numbers represent long tons of 2,240 pounds, hundredweights of 112 pounds, stone of 14 pounds, and pounds. Thus 4-2-3-7 equals 9,233 pounds; 3-2-2 equals 366 pounds.

218. Foreign Weights and Measures

Table 235. Foreign Weights and Measures

Denominations	Where used	American equivalents	Denominations	Where used	American equivalents
Almude.....	Portugal.....	4.422 gals.	Fanega (dry).....	Ecuador, Salvador..	1.5745 bu.
Ardeb.....	Egypt.....	5.6188 bu.	Fanega.....	Chile.....	2.75268 bu.
Are.....	Metric.....	0.02471 acre.	Fanega.....	Guatemala, Spain..	1.53 bu.
Arr't'l or li'ra.....	Portugal.....	1.0119 lbs.	Fanega.....	Mexico.....	2.57716 bu.
Arroba.....	Argentine Republic.	25.32 lbs.	Fanega (double).....	Uruguay.....	7.776 bu.
Arroba.....	Brazil.....	32.38 lbs.	Fanega (single).....	Uruguay.....	3.888 bu.
Arroba.....	Cuba.....	25.36 lbs.	Fanega.....	Venezuela.....	3.334 bu.
Arroba.....	Paraguay.....	25.32 lbs.	Fanega (liquid).....	Spain.....	16 gals.
Arroba.....	Venezuela.....	25.40 lbs.	Feddán.....	Egypt.....	1.04 acres.
Arroba (liquid).....	Cuba, Spain and Venezuela.	4.263 gals.	Frall (rais's).....	Spain.....	50 lbs.
Arshine.....	Russia.....	28 in.	Frasco.....	Argentine Republic..	2.5098 liq. qts.
Arshine (sq.).....	Russia.....	5.44 sq. ft.	Frasco.....	Mexico.....	2.5 liq. qts.
Artel.....	Morocco.....	1.12 lbs.	Frasila.....	Zanzibar.....	35 lbs.
Baril.....	Argentine Republic. and Mexico.....	20.077 gals. 20.0787 gals.	Fuder.....	Luxemburg.....	264.18 gals.
Barrel.....	Malta (customs).....	11.2 gals.	Funt.....	Russia.....	0.9028 lb.
Berkovets.....	Russia.....	361.128 lbs.	Gallon.....	British Empire.....	1.20094 U.S. gal.
Bongkal.....	Fed. Malay States..	832 grains.	Garnice.....	Poland.....	1.0567 gal.
Bouw.....	Sumatra.....	7,096.5 sq. metrs.	Gram.....	Metric.....	15.432 grains.
Bu.....	Japan.....	0.12 inch.	Hectare.....	Metric.....	2,471 acres.
Bushel.....	British Empire.....	1.03205 U.S. bu.	Hectolitre: Dry.....	Metric.....	2.838 bu.
Caffiso.....	Malta.....	5.40 gals.	Hectolitre: Liquid....	Metric.....	26.418 gals.
Candy.....	India (Bombay)....	569 lbs.	Jarib.....	Persia (Ncw).....	2.471 acres.
Candy.....	India (Madras)....	500 lbs.	Joch.....	Austria (Germany)	1.422 acres.
			Joch.....	Hungary.....	1.067 acres.
			Ken.....	Japan.....	5.97 feet.

Cantar.....	Egypt.....	99.05 lbs.
Cantar.....	Morocco.....	112 lbs.
Cantar.....	Turkey.....	124.45 lbs.
Cantaro.....	Malta.....	175 lbs.
Cast, Metric.....	Metric.....	3.086 grains.
Catty.....	China.....	1.333 $\frac{1}{2}$ lbs.
Catty.....	Japan.....	1.32 lbs.
Catty.....	Java, Malacca.....	1.36 lbs.
Catty.....	Thailand.....	2 $\frac{1}{4}$ lbs.
Catty (stand).....	Thailand.....	1.32 lbs.
Catty.....	Sumatra.....	2.12 lbs.
Centaro.....	Central America.....	4.2631 gals.
Centner.....	Brunswick.....	117.5 lbs.
Centner.....	Bremen.....	127.5 lbs.
Centner.....	Denmark, Norway.....	110.23 lbs.
Centner.....	Prussia.....	113.44 lbs.
Centner.....	Sweden.....	93.7 lbs.
Centner.....	Double or metric.....	220.46 lbs.
Chetvert.....	Russia.....	5.957 bu.
Ch'ih.....	China.....	12.60 inches.
Ch'ih (metric).....	China.....	1 meter.
Cho.....	Japan.....	2.451 acres.
Comb.....	England.....	4.1282 bu.
Coyan.....	Thailand.....	2,645.5 lbs.
Cuadra.....	Argentine Republic.....	4.2 acres.
Cuadra.....	Paraguay.....	94.70 yds.
Cuadra (sq.).....	Paraguay.....	1.85 acres.
Cuadra.....	Uruguay.....	1.82 acres.
Cubic meter.....	Metric.....	35.3 cu. ft.
Cwt. (hund. weight).....	British.....	112 lbs.
Dessiatine.....	Russia.....	2.6997 acres.
Drachma (new).....	Greece.....	15.43 gr., or 1 grm.

Kilogram kilo.....	Metric.....	2.2046 lbs.
Kilometre.....	Metric.....	0.62137 mile.
Klafter.....	Austria (Germany).....	2.074 yds.
Koku.....	Japan.....	5.119 bu.
Kwamme.....	Japan.....	8.2673 lbs.
Last.....	Belgium, Netherlands.....	85.134 bu.
Last.....	England.....	82.56 bu.
Last.....	Germany.....	2 metric tons. (4,409 + lbs.).
Last.....	Prussia.....	112.29 bu.
Last.....	Scotland, Ireland.....	82.564 bu.
League (land).....	Paraguay.....	4.633 acres.
Li.....	China.....	1,890 ft.
Libra (lb.).....	Argentine Republic.....	1.0128 lbs.
Libra.....	Central America.....	1.014 lbs.
Libra.....	Chile.....	1.014 lbs.
Libra.....	Cuba.....	1.0143 lbs.
Libra.....	Mexico.....	1.01467 lbs.
Libra.....	Peru.....	1.0143 lbs.
Libra.....	Uruguay.....	1.0143 lbs.
Libra.....	Venezuela.....	1.0143 lbs.
Litre.....	Metric.....	1.0567 liq. qts.
Litre.....	Metric.....	0.90810 dry qts.
Livre (lb.).....	Greece.....	1.1 lbs.
Livre.....	Guiana (Dutch).....	1.089 lbs.
Load, timber.....	England.....	50 cu. ft.
Lumber (std.).....	in Europe.....	165 cu. ft., or 1,980 ft. b. m.
Manzana.....	Nicaragua.....	1.742 acres.
Manzana.....	Costa Rica, Salvador.....	1.727 acres.

Table 235. Foreign Weights and Measures—Continued

Denominations	Where used	American equivalents	Denominations	Where used	American equivalents
Marc.....	Bolivia.....	0.507 lb.	Sagene.....	Russia.....	7 feet.
Maund.....	India.....	82 2-7 lbs.	Salm.....	Malta.....	8.2 bu.
Metre.....	Metric.....	39.37 inches.	Se.....	Japan.....	0.02451 acre.
Mil.....	Denmark.....	4.68 miles.	Seer.....	India.....	2 2-35 lbs.
Mil (geographic).....	Denmark.....	4.61 miles.	Shaku.....	Japan.....	11.9303 inches.
Milla.....	Nicaragua.....	1.1594 miles.	Sho.....	Japah.....	1.91 liq. quarts.
Milla.....	Honduras.....	1.1493 miles.	Skalpund.....	Sweden.....	0.937 lbs.
Mina (old).....	Greece.....	2.202 lbs.	Stone.....	British.....	14 lbs.
Morgen.....	Prussia.....	0.63 acre.	Sun.....	Japan.....	1.193 inches.
Oke.....	Egypt.....	2.8052 lbs.	Tael Kuping.....	China.....	575.64 grs. (troy).
Oke (Ocque).....	Greece.....	2.82 lbs.	Tan.....	Japan.....	0.25 acre.
Oke.....	Turkey.....	2.828 lbs.	Tchetvert.....	Russia.....	5.96 bu.
Pic.....	Egypt.....	22.83 inches.	To.....	Japan.....	2.05 pecks.
Picul.....	Borneo & Celebes.....	135.64 lbs.	Ton.....	Space measure.....	40 cu. ft.
Picul.....	China.....	133½ lbs.	Tonde cereals.....	Denmark.....	3.9480 bu.
Picul.....	Java.....	136.16 lbs.	Tonde Land.....	Denmark.....	1.36 acres.
Picul.....	Philippine Republic.....	139.44 lbs.	Tonne.....	France.....	2204.62 lbs.
Pie.....	Argentine Republic.....	0.94708 foot.	Tsubo.....	Japan.....	35.58 sq. ft.
Pie.....	Spain.....	0.91416 foot.	Tsun.....	China.....	1.26 inches.
Pik.....	Turkey.....	27.9 inches.	Tunna (wheat).....	Sweden.....	4.5 bu.
Pood.....	Russia.....	36.113 lbs.	Tunnland.....	Sweden.....	1.22 acres.
Pund (lb).....	Denmark.....	1.102 lbs.	Vara.....	Argentine Republic.....	34.0944 inches.
Quart.....	British Empire.....	1.20094 liq. qt.	Vara.....	Costa Rica, Salvador.....	32.913 inches.
Quart.....	British Empire.....	1.03205 dry qt.	Vara.....	Guatemala.....	32.909 inches.
Quarter.....	Great Britain.....	8.256 bu.	Vara.....	Honduras.....	32.953 inches.

Quintal	Argentine Republic	101.28 lbs.	Vara	Nicaragua	33.057 inches.
Quintal	Brazil	120.54 lbs.	Vara	Chile and Peru	32.913 inches.
Quintal	Castile, Peru	101.43 lbs.	Vara	Cuba	33.386 inches.
Quintal	Chile	101.41 lbs.	Vara	Mexico	32.992 inches.
Quintal	Mexico	101.47 lbs.	Vedro	Russia	2.707 gals.
Quintal	Metric	220.46 lbs.	Verst	Russia	0.663 mile.
Rottle	Israel	6.35 lbs.	Vloka	Poland	41.50 acres.
Sack (flour)	England	280 lbs.	Wey	Scotland & Ireland	41.282 bu.

219. Properties of Materials

a. Weights and Specific Gravities of Certain Materials.

Table 236. *Weights and Specific Gravities*

Substance	Weight (pounds per cubic feet)	Specific gravity
BITUMINOUS SUBSTANCES:		
Asphaltum.....	81	1. 1-1. 5
Coal, anthracite.....	97	1. 4-1. 7
Coal, bituminous.....	84	1. 2-1. 5
Coal, charcoal, pine.....	23	0. 28-0. 44
Coal, charcoal, oak.....	33	0. 47-0. 57
Coal, coke.....	75	1. 0-1. 4
Coal, lignite.....	78	1. 1-1. 4
Coal, peat, turf, dry.....	47	0. 65-0. 85
Graphite.....	131	1. 9-2. 3
Paraffine.....	56	0. 87-0. 91
Petroleum.....	54	0. 87
Petroleum, benzine.....	46	0. 73-0. 75
Petroleum, gasoline.....	42	0. 66-0. 69
Petroleum, refined.....	50	0. 79-0. 82
Pitch.....	69	1. 07-1. 15
Tar, bituminous.....	75	1. 20
BUILDING MATERIALS, VARIOUS:		
Ashes, cinders.....	40-45	-----
Cement, portland, loose.....	90	-----
Cement, portland, set.....	183	2. 7-3. 2
Lime, gypsum, loose.....	53-64	-----
Mortar, set.....	103	1. 4-1. 9
Slags, bank screenings.....	98-117	-----
Slags, bank slag.....	67-72	-----
Slags, machine slag.....	96	-----
Slags, slag sand.....	49-55	-----
COAL AND COKE, PILED:		
Coal, anthracite.....	47-58	-----
Coal, bituminous, lignite.....	40-54	-----
Coal, charcoal.....	10-14	-----
Coal, coke.....	23-32	-----
Coal, peat, turf.....	20-26	-----
EARTH, ETC., EXCAVATED:		
Clay, damp, plastic.....	110	-----
Clay, dry.....	63	-----
Clay and gravel, dry.....	100	-----
Earth, dry, loose.....	76	-----
Earth, dry, packed.....	95	-----
Earth, moist, loose.....	78	-----
Earth, moist, packed.....	96	-----
Earth, mud, flowing.....	108	-----
Earth, mud, packed.....	115	-----
Riprap, limestone.....	80-85	-----
Riprap, sandstone.....	90	-----
Riprap, shale.....	105	-----

Table 236. *Weights and Specific Gravities*—Continued

Substance	Weight (pounds per cubic feet)	Specific gravity
EARTH, ETC., EXCAVATED—Continued		
Sand, gravel, dry, loose.....	90-105	-----
Sand, gravel, dry, packed.....	100-120	-----
Sand, gravel, dry, wet.....	118-120	-----
EXCAVATIONS IN WATER:		
Clay.....	80	-----
River mud.....	90	-----
Sand or gravel.....	60	-----
Sand or gravel and clay.....	65	-----
Soil.....	70	-----
Stone riprap.....	65	-----
GASES, VARIOUS:		
Air, 0° C. 760 mm.....	. 08071	1
Ammonia.....	. 0478	0. 5920
Carbon dioxide.....	. '234	1. 5291
Carbon monoxide.....	. 0781	0. 9673
Gas, illuminating.....	. 028-. 036	0. 35-0. 45
Gas, natural.....	. 038-. 039	0. 47-0. 48
Hydrogen.....	. 00559	0. 0693
Nitrogen.....	. 0784	0. 9714
Oxygen.....	. 0892	1. 1056
LIQUIDS, VARIOUS:		
Alcohol, 100%.....	49	0. 79
Acid, muriatic, 40%.....	75	1. 20
Acid, nitric, 91%.....	94	1. 50
Acid, sulfuric, 87%.....	112	1. 80
Lye, soda, 66%.....	106	1. 70
Oils, mineral, lubricants.....	57	0. 90-0. 93
Oils, vegetable.....	58	0. 91-0. 94
Water, 4° C. (maximum density).....	62. 428	1. 0
Water, 100° C.....	59. 830	0. 9584
Water, ice.....	56	0. 88-0. 92
Water, sea.....	64	1. 02-1. 03
Water, snow, fresh fallen.....	8	0. 125
MASONRY, ASHLAR:		
Granite, syenite, gneiss.....	165	2. 3-3. 0
Limestone, marble.....	160	2. 3-2. 8
Sandstone, bluestone.....	140	2. 1-2. 4
MASONRY, BRICK:		
Pressed brick.....	140	2. 2-2. 3
Common brick.....	120	1. 8-2. 0
Soft brick.....	100	1. 5-1. 7
MASONRY, CONCRETE:		
Cement, stone, sand.....	144	2. 2-2. 4
Cement, slag, etc.....	130	1. 9-2. 3
Cement, cinder, etc.....	100	1. 5-1. 7
MASONRY, DRY RUBBLE:		
Granite, syenite, gneiss.....	130	1. 9-2. 3
Limestone, marble.....	125	1. 9-2. 1
Sandstone, bluestone.....	110	1. 8-1. 9

Table 236. *Weights and Specific Gravities*—Continued

Substance	Weight (pounds per cubic feet)	Specific gravity
MASONRY, MORTAR RUBBLE:		
Granite, syenite, gneiss.....	155	2. 2-2. 8
Limestone, marble.....	150	2. 2-2. 6
Sandstone, bluestone.....	130	2. 0-2. 2
METALS, ALLOYS, ORES:		
Aluminum, cast, hammered.....	165	2. 55-2. 75
Brass, cast, rolled.....	534	8. 4-8. 7
Bronze, 7.9 to 14% Sn.....	509	7. 4-8. 9
Bronze, aluminum.....	481	7. 7
Copper, cast, rolled.....	556	8. 8-9. 0
Copper ore, pyrites.....	262	4. 1-4. 3
Gold, cast, hammered.....	1205	19. 25-19. 3
Iron, cast, pig.....	450	7. 2
Iron, ferrosilicon.....	437	6. 7-7. 3
Iron, spiegeleiser.....	468	7. 5
Iron, wrought.....	485	7. 6-7. 9
Iron ore, hematite.....	325	5. 2
Iron ore, hematite in bank.....	160-180	-----
Iron ore, hematite loose.....	130-160	-----
Iron ore, limonite.....	237	3. 6-4. 0
Iron ore, magnetite.....	315	4. 9-5. 2
Iron slag.....	172	2. 5-3. 0
Lead.....	710	11. 37
Lead ore, galena.....	465	7. 3-7. 6
Magnesium, alloys.....	112	1. 74-1. 83
Manganese.....	475	7. 2-8. 0
Manganese ore, pyrolusite.....	259	3. 7-4. 6
Mercury.....	849	13. 6
Monel metal.....	556	8. 8-9. 0
Nickel.....	565	8. 9-9. 2
Platinum, cast, hammered.....	1330	21. 1-21. 5
Silver, cast, hammered.....	656	10. 4-10. 6
Steel, rolled.....	490	7. 85
Tin, cast, hammered.....	459	7. 2-7. 75
Tin ore, cassiterite.....	418	6. 4-7. 0
Zinc, cast, rolled.....	440	6. 9-7. 2
Zinc ore, blende.....	253	3. 9-4. 2
MINERALS:		
Asbestos.....	153	2. 1-2. 8
Barite.....	281	4. 50
Basalt.....	184	2. 7-3. 2
Bauxite.....	159	2. 55
Borax.....	109	1. 7-1. 8
Chalk.....	137	1. 8-2. 6
Clay, marl.....	137	1. 8-2. 6
Dolomite.....	181	2. 9
Feldspar, orthoclase.....	159	2. 5-2. 6
Gneiss, serpentine.....	159	2. 4-2. 7
Granite, syenite.....	175	2. 5-3. 1

Table 236. *Weights and Specific Gravities—Continued*

Substance	Weight (pounds per cubic foot)	Specific gravity
MINERALS—Continued		
Greenstone, trap.....	187	2. 8-3. 2
Gypsum, alabaster.....	159	2. 3-2. 8
Hornblende.....	187	3. 0
Limestone, marble.....	165	2. 5-2. 8
Magnesite.....	187	3. 0
Phosphate rock, apatite.....	200	3. 2
Porphyry.....	172	2. 6-2. 9
Pumice, natural.....	40	0. 37-0. 90
Quartz, flint.....	165	2. 5-2. 8
Sandstone, bluestone.....	147	2. 2-2. 5
Shale, slate.....	175	2. 7-2. 9
Soapstone, talc.....	169	2. 6-2. 8
SOLIDS, VARIOUS:		
Cereals, barley (bulk).....	39	-----
Cereals, corn, rye (bulk).....	48	-----
Cereals, oats (bulk).....	32	-----
Cereals, wheat (bulk).....	48	-----
Cotton, flax, hemp.....	93	1. 47-1. 50
Fats.....	58	0. 90-0. 97
Flour, loose.....	28	0. 40-0. 50
Flour, pressed.....	47	0. 70-0. 80
Glass, common.....	156	2. 40-2. 60
Glass, crystal.....	184	2. 90-3. 00
Glass, plate or crown.....	161	2. 45-2. 72
Hay and straw (bales).....	20	-----
Leather.....	59	0. 86-1. 02
Paper.....	58	0. 70-1. 15
Potatoes, piled.....	42	-----
Rubber, caoutchouc.....	59	0. 92-0. 96
Rubber goods.....	94	1. 0-2. 0
Salt, granulated, piled.....	48	-----
Saltpeter.....	67	-----
Starch.....	96	1. 53
Sulfur.....	125	1. 93-2. 07
Wool.....	82	1. 32
STONE, QUARRIED, PILED:		
Basalt, granite, gneiss.....	96	-----
Greenstone, hornblende.....	107	-----
Limestone, marble, quartz.....	9	-----
Sandstone.....	82	-----
Shale.....	92	-----
TIMBER, U.S. SEASONED:		
Moisture content by weight (seasoned timber 15 to 20%; green timber up to 50%):		
Ash, white, red.....	40	0. 62-0. 65
Cedar, white, red.....	22	0. 32-0. 38
Chestnut.....	41	0. 66
Cypress.....	30	0. 48

Table 236. *Weights and Specific Gravities—Continued*

Substance	Weight (pounds per cubic foot)	Specific gravity
TIMBER, U.S. SEASONED—Continued		
Elm, white.....	45	0. 72
Fir, Douglas Spruce.....	32	0. 51
Fir, eastern.....	25	0. 40
Hemlock.....	29	0. 42–0. 52
Hickory.....	49	0. 74–0. 84
Locust.....	46	0. 73
Maple, hard.....	43	0. 68
Maple, white.....	33	0. 53
Oak, chestnut.....	54	0. 86
Oak, live.....	59	0. 95
Oak, red, black.....	41	0. 65
Oak, white.....	46	0. 74
Pine, Oregon.....	32	0. 51
Pine, red.....	30	0. 48
Pine, white.....	26	0. 41
Pine, yellow, longleaf.....	44	0. 70
Pine, yellow, shortleaf.....	38	0. 61
Poplar.....	30	0. 48
Redwood, California.....	26	0. 42
Spruce, white, black.....	27	0. 40–0. 46
Walnut, black.....	38	0. 61
Walnut, white.....	26	0. 41

The specific gravities of solids and liquids refer to water at 4° C. and 760 mm. pressure. The weights per cubic foot are derived from average specific gravities, except where stated that weights are for bulk, heaped or loose material, etc.

b. Weights of Certain Building Materials.

Table 237. *Weights of Building Materials*

Material	Weight, pounds per square foot
CEILINGS:	
Gypsum ceiling block, 2" thick unplastered.....	10
Plaster, on tile or concrete.....	5
Plaster, ¾", and metal lath.....	8
Plaster, ¾", and wood lath.....	8
Plaster board, unplastered.....	3
Suspended, metal lath and plaster.....	10
FLOORS:	
Cement finish, per inch thick.....	12
Cinder concrete, per inch thick.....	9
Cinder concrete fill, per inch thick.....	5
Gypsum slab, per inch thick.....	5
Hardwood flooring, ¾" thick.....	4
Sheathing, white, red, or Oregon pine, spruce, or hemlock, ¾" thick.....	2½

Table 237. *Weights of Building Materials—Continued*

Material	Weight, pounds per square foot
FLOORS—Continued	
Sheathing, yellow pine, 1" thick	4
Terrazzo, tile, mastic, linoleum, per inch thick, including base ..	12
Wood block, creosoted, 3" thick	15
PARTITIONS:	
Channel studs, metal lath, cement plaster, solid, 2" thick	20
Hollow clay tile, 2"	13
Hollow clay tile, 3"	16
Hollow clay tile, 4"	18
Hollow clay tile, 5"	20
Hollow clay tile, 6"	25
Hollow clay tile, 8"	30
Hollow clay tile, 10"	35
Plaster, ½", on gypsum block or clay tile (one side)	4
Solid gypsum block, 2"	9½
Solid gypsum block, 3"	13
Steel partitions	4
Studs, 2" x 4" plaster board, ½" plaster both sides	18
Studs, 2" x 4" wood or metal lath, ¾" plaster both sides	18
ROOFS:	
Corrugated metal	(Par. 180)
Ready roofing, 3 ply	1
Roofing felt, 3 ply and gravel	5½
Roofing felt, 5 ply and gravel	6½
Roofing felt, 3 ply and slag	5½
Roofing felt, 5 ply and slag	5½
Shingles, wood	2
Tile or slate	5-20
WALLS:	
Brick, 9" thick	84
Brick, 13" thick	121
Brick, 18" thick	168
Brick, 22" thick	205
Brick, 26" thick	243
Brick 4", tile backing 4"	60
Brick 4", tile backing 8"	75
Brick 8", tile backing 4"	100
Brick 9", tile backing 8"	115
Corrugated metal siding	(Par. 180)
Limestone 4", brick 9"	140
Limestone 4", brick 13"	175
Limestone 4", tile 8"	90
Limestone 4", tile 12"	100
Wall tile, 6" thick	30
Wall tile, 8" thick	33
Wall tile, 10" thick	40
Wall tile, 12" thick	45
Windows, glass, frame, and sash	8

c. Strengths of Certain Materials.

Table 238. Strengths of Materials, Metals and Alloys

Material	Stress in kips per square inch					Modulus of elasticity (pounds per square inch)	Elongation percent
	Tension ultimate	Elastic limit	Compression ultimate	Bending ultimate	Shearing ultimate		
Aluminum, bars, sheets	24-28	12-14					
Aluminum, wire, annealed	20-35	14					
Brass, 50% Zn	31	17.9	117	33.5			5
Brass, cast, common	18-24	6	30	20	36	9,000,000	
Brass, wire, hard	80						
Brass, wire, annealed	50	16				14,000,000	
Bronze, aluminum 5 to 7½%	75	40	120				
Bronze, Tobin, cast, 38% Zn	66						
Bronze, Tobin, rolled, 1½% Sn	80	40				14,500,000	
Bronze, Tobin, c. rolled, ½% Pb	100						
Copper, plates, rods, bolts	32-35	10	32				
Iron, cast, gray	18-24			25-33			
Iron, cast, malleable	27-35	15-20	46	30	40		
Iron, wrought, shapes	48	26	Tensile	Tensile	¾ tensile	28,000,000	
Steel, bridges, buildings, ships	60-72	33	Tensile	Tensile	¾ tensile	29,000,000	
Steel, cars	50-65	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, cast, hard	80	36	Tensile	Tensile	¾ tensile	29,000,000	1 17
Steel, cast, medium	70	31.5	Tensile	Tensile	¾ tensile	29,000,000	1 20
Steel, cast, soft	60	27	Tensile	Tensile	¾ tensile	29,000,000	1 24
Steel, locomotives, stationary boilers	55-65	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, plates for cold pressing	48-58	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, rivet, boiler	45-55	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, rivet, bridges, buildings, locomotives, cars.	52-62	28	Tensile	Tensile	¾ tensile	29,000,000	

Steel, rivet, high-tensile-----	70-85	38-----	Tensile-----	Tensile-----	¾ tensile-----	29, 000, 000	-----
Steel, rivet, ships-----	55-65	30-----	Tensile-----	Tensile-----	¾ tensile-----	29, 000, 000	-----
Steel, structural nickel (3.25% Ni)-----	85-100	50-----	Tensile-----	Tensile-----	¾ tensile-----	29, 000, 000	(2)
Steel, structural silicon-----	80-95	45-----	Tensile-----	Tensile-----	¾ tensile-----	29, 000, 000	-----
Steel wire, annealed-----	80	40-----	-----	-----	-----	-----	-----
Steel wire, bridge cable-----	215	95-----	-----	-----	-----	-----	-----
Steel wire, unannealed-----	120	60-----	-----	-----	-----	-----	-----

¹ 2" gage length.
² $\frac{1,500,000}{\text{tensile strength}}$, 8" gage length.

Table 238. *Strengths of Materials, Building Materials*

Material	Average ultimate stress (pounds per square inch)			Safe working stress (pounds per square inch)			Modulus of elasticity (pounds per square inch)
	Compression	Tension	Bending	Compression	Bearing	Shearing	
Masonry, brick, common.....	10, 000	200	600				
Masonry, granite.....				420	600		
Masonry, limestone, bluestone.....				350	500		
Masonry, sandstone.....				280	400		
Masonry, rubble.....				140	250		
Ropes, cast steel hoisting.....		80, 000					
Ropes, manila.....		8, 000					
Ropes, standing, derrick.....		70, 000					
Stone, bluestone.....	12, 000	1, 200	2, 500	1, 200	1, 200	200	7, 000, 000
Stone, granite, gneiss.....	12, 000	1, 200	1, 600	1, 200	1, 200	200	7, 000, 000
Stone, limestone, marble.....	8, 000	800	1, 500	800	800	150	7, 000, 000
Stone, sandstone.....	5, 000	150	1, 200	500	500	150	3, 000, 000
Stone, slate.....	10, 000	3, 000	5, 000	1, 000	1, 000	175	14, 000, 000

d. *Coefficients of Expansion of Certain Materials.* The coefficient of linear expansion (ϵ) of a material is the change in length, per unit of length, for a change of one degree of temperature. The coefficient of surface expansion is approximately two times the linear coefficient, and the coefficient of volume expansion, for solids, is approximately three times the linear coefficient.

- (1) A bar, free to move, will increase in length with an increase in temperature and will decrease in length with a decrease in temperature. The change in length will be ϵtl , where ϵ is the coefficient of linear expansion, t the change in temperature, and l the length. If the ends of a bar are fixed, a change in temperature (t) will cause a change in the unit stress of $E\epsilon t$, and in the total stress of $AE\epsilon t$, where A is the cross sectional area of the bar and E the modulus of elasticity.
- (2) Table 239 gives the coefficient of linear expansion for 100° , of 100 times the value indicated above.

Example: A piece of medium steel is exactly 40 feet long at 60° F. Find the length at 90° F. assuming the ends free to move.

$$\text{Change of length} = \epsilon tl = \frac{.00067 \times 30 \times 40}{100} = .00804 \text{ foot.}$$

- (3) The length at 90° F. is 40.00804 feet.

Example: A piece of medium steel is exactly 40 feet long and the ends are fixed. If the temperature increases 30° F., what is the resulting change in the unit stress?

$$\begin{aligned} \text{Change in unit stress} &= E\epsilon t = \frac{29,000,000 \times 0.00067 \times 30}{100} \\ &= 5830 \text{ lbs. per sq. in.} \end{aligned}$$

Table 239. Coefficients of Expansion of Materials for 100 Degrees = 100°C

Materials	Linear expansion		Materials	Linear expansion			
	Centigrade	Fahrenheit		Centigrade	Fahrenheit		
METALS AND ALLOYS:			METALS AND ALLOYS—Continued				
Aluminum, wrought.....	0. 00231	0. 00128	Steel, stainless, 18-8.....	. 00178	.00099		
Brass.....	. 00188	. 00104	Zinc, rolled.....	. 00311	. 00173		
Bronze.....	. 00181	. 00101	STONE AND MASONRY:				
Copper.....	. 00168	. 00093	Ashlar masonry.....	. 00063	. 00035		
Iron, cast, gray.....	. 00106	. 00059	Brick masonry.....	. 00055	. 00031		
Iron, wrought.....	. 00120	. 00067	Cement, portland.....	. 00107	. 00059		
Iron, wire.....	. 00124	. 00069	Concrete.....	. 00143	. 00079		
Lead.....	. 00286	. 00159	Granite.....	. 00084	. 00047		
Magnesium, various alloys.....	. 0029	. 0016	Limestone.....	. 00080	. 00044		
Nickel.....	. 00126	. 00070	Marble.....	. 00100	. 00056		
Steel, cast.....	. 00110	. 00061	Plaster.....	. 00166	. 00092		
Steel, hard.....	. 00132	. 00073	Rubble masonry.....	. 00063	. 00035		
Steel, medium.....	. 00120	. 00067	Sandstone.....	. 00110	. 00061		
Steel, soft.....	. 00110	. 00061	Slate.....	. 00104	. 00058		
TIMBER			TIMBER				
Fir.....	{ 0. 00037	{ 0. 00021	Fir.....	{ 0. 0058	{ 0. 0032		
Maple.....			{ . 00064			Maple.....	{ . 0048
Oak.....			{ . 00049			Oak.....	{ . 0054
Pine.....			{ . 00054			Pine.....	{ . 0034
parallel to fiber.....			perpendicular to fiber.....				

EXPANSION OF WATER

Maximum Density = 1

° C.	Volume	° C.	Volume	° C.	Volume	° C.	Volume
0.....	1. 000126	20.....	1. 001732	50.....	1. 011877	80.....	1. 029003
4.....	1. 000000	30.....	1. 004234	60.....	1. 016954	90.....	1. 035829
10.....	1. 000257	40.....	1. 007627	70.....	1. 022384	100.....	1. 043116

220. Density of Gases

Table 240. Density of Gases

Gas	Weight		Specific gravity	
	Grams per liter	Pounds per cubic foot	Air=0	0=1
Air.....	1. 2930	0. 00872	1. 0000	0. 9048
Acetylene.....	1. 1791	0. 07361	0. 9119	0. 8251
Ammonia.....	0. 7708	0. 04812	0. 5961	0. 5394
Argon.....	1. 7809	0. 11118	1. 3773	1. 2462
Bromine.....	7. 14	0. 446	5. 52	5. 00
Butane.....	2. 594	0. 1619	2. 006	1. 815
Carbon dioxide.....	1. 9768	0. 12341	1. 5289	1. 3833
Carbon monoxide.....	1. 2504	0. 07806	0. 9671	0. 8750
Chlorine.....	3. 221	0. 2011	2. 491	2. 254
Cial gas.....	0. 41-0. 96	0. 026-0. 060	0. 32-0. 74	0. 29-0. 67
Cyanogen.....	2. 323	0. 1450	1. 797	1. 626
Ethane.....	1. 3562	0. 08467	1. 0489	0. 9490
Ethylene.....	1. 2609	0. 07872	0. 9752	0. 8823
Fluorine.....	1. 70	0. 106	1. 31	1. 19
Helium.....	0. 1785	0. 01115	0. 1381	0. 1249
Hydrobromic acid.....	3. 616	0. 2257	2. 797	2. 530
Hydrochloric acid.....	1. 6398	0. 10237	1. 2682	1. 1475
Hydrofluoric acid.....	0. 922	0. 0576	0. 713	0. 645
Hydrogen.....	0. 08987	0. 00561	0. 06950	0. 06289
Hydrogen sulfide.....	1. 538	0. 09602	1. 189	1. 076
Krypton.....	3. 708	0. 2315	2. 868	2. 595
Methane.....	0. 7168	0. 04475	0. 5544	0. 5016
Methyl chloride.....	2. 304	0. 1438	1. 782	1. 612
Methyl ether.....	2. 110	0. 1317	1. 632	1. 477
Neon.....	0. 9002	0. 05620	0. 6962	0. 6299
Nitrogen.....	1. 2507	0. 07808	0. 9673	0. 8752
Nitric oxide.....	1. 3402	0. 08367	1. 0365	0. 9378
Nitrous oxide.....	1. 9777	0. 12347	1. 5296	1. 3839
Oxygen.....	1. 42905	0. 08921	1. 1052	1. 0000
Propane.....	2. 0196	0. 12608	1. 5620	1. 4132
Steam at 100° C.....	0. 598	0. 0373	0. 462	0. 418
Sulphur dioxide.....	2. 9266	0. 18270	2. 2634	2. 0479
Xenon.....	5. 851	0. 3653	4. 525	4. 094

Notes. The gases in this table, or the elements of which they are composed, are the isotopes or mixtures of isotopes normally occurring in nature.

221. Contents of Horizontal Tanks

The cubic content of a horizontal cylindrical tank of circular or elliptical cross section is given by the formula—

$$C = \frac{\pi}{4} \left(\frac{d^2 l}{231} \right) = 0.0034 d^2 l$$

where C is the capacity in gallons and d and l are, respectively, the diameter and the length in inches. For a tank partially filled with

liquid, the volume of liquid as a percentage of the total capacity is related to the depth of liquid as a percentage of the total depth (diameter) as shown in table 241. Use columns 1 and 1a if the percentage depth is 50 percent or less; columns 2 and 2a if greater than 50 percent.

Table 241. Capacities of Partially Filled Tanks

Percent of depth		Percent of capacity		Percent of depth		Percent of capacity	
1—filled	2—unfilled	1a—filled	2a—unfilled	1—filled	2—unfilled	1a—filled	2a—unfilled
1	99	0.20	99.80	26	74	20.73	79.27
2	98	0.50	99.50	27	73	21.86	78.14
3	97	0.90	99.10	28	72	23.00	77.00
4	96	1.34	98.66	29	71	24.07	75.93
5	95	1.87	98.13	30	70	25.31	74.69
6	94	2.45	97.55	31	69	26.48	73.52
7	93	3.07	96.93	32	68	27.66	72.34
8	92	3.74	96.26	33	67	28.84	71.16
9	91	4.45	95.55	34	66	30.03	69.97
10	90	5.20	94.80	35	65	31.19	68.81
11	89	5.98	94.02	36	64	32.44	67.56
12	88	6.80	93.20	37	63	33.66	66.34
13	87	7.64	92.36	38	62	34.90	65.10
14	86	8.50	91.50	39	61	36.14	63.86
15	85	9.40	90.60	40	60	37.39	62.61
16	84	10.32	89.68	41	59	38.64	61.36
17	83	11.27	88.73	42	58	39.89	60.11
18	82	12.24	87.76	43	57	41.14	58.86
19	81	13.23	86.77	44	56	42.40	57.60
20	80	14.23	85.77	45	55	43.66	56.34
21	79	15.26	84.74	46	54	44.92	55.08
22	78	16.32	83.68	47	53	46.19	53.81
23	77	17.40	82.60	48	52	47.45	52.55
24	76	18.50	81.50	49	51	48.73	51.27
25	75	19.61	80.39	50	50	50.00	50.00

222. Volume of Piled Sand or Gravel

To obtain the capacity of a conical pile, enter figure 110 on the horizontal line at the bottom with the height of the pile in feet. Proceed upward to the point where the proper curve intersects this vertical line. Proceed horizontally from this intersection to the column at the left and read capacity in tons. For example, a 24-foot-high conical pile of gravel will hold 1,770 tons. (See arrow and dotted line on chart.) For a pile shaped as shown, add to the capacity of one conical pile the capacity of an A-shaped pile from the "scale in tons per linear foot of storage." For example (see arrow and dotted line) an A-shaped pile of sand 22 feet high holds 28.8 tons per linear foot.

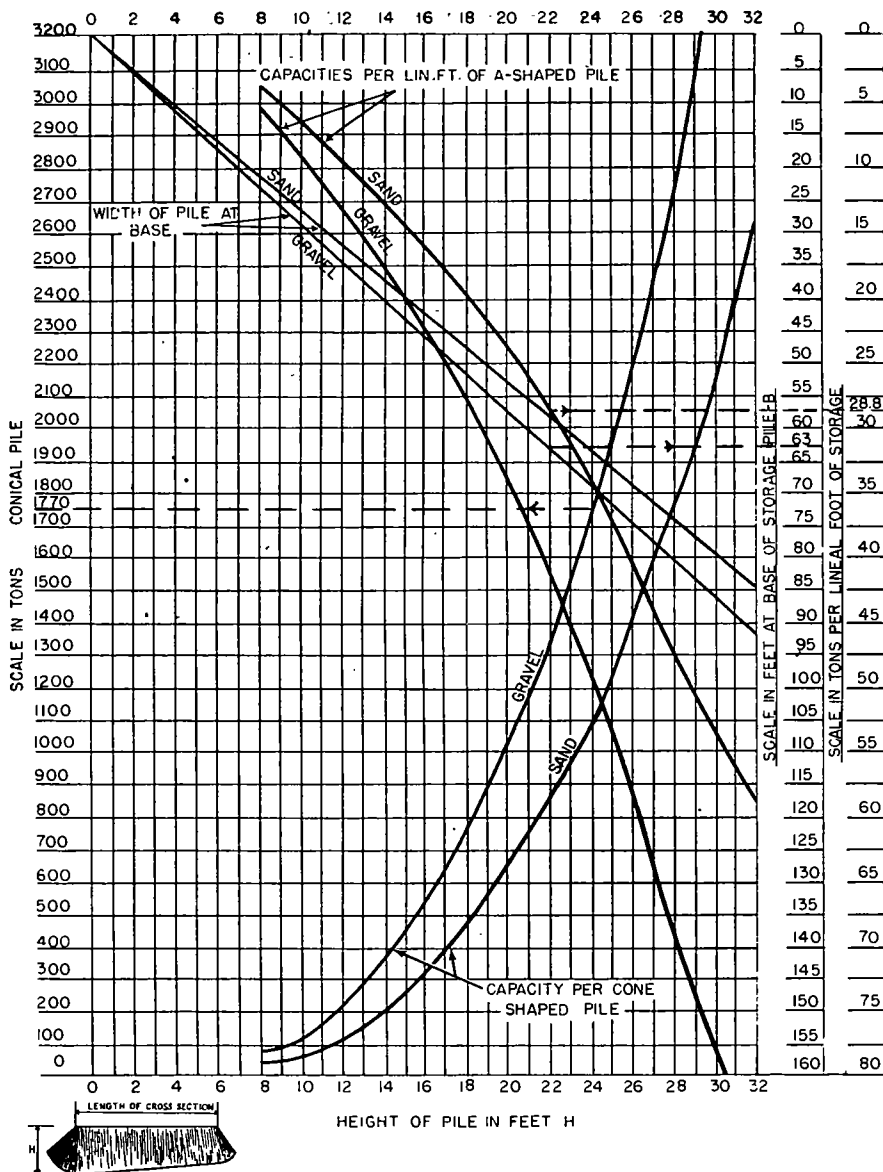


Figure 110. Volume of piled sand or gravel.

223. Safe Loads on Wood Piles

Safe loads may be limited by maximum values considered allowable, by skin friction, or by column action. The values obtained are approximations only.

a. Maximum Allowable Loads. All pile formulas being empirical, maximum loads per pile for semipermanent structures are normally limited to the following:

Pile diameter, inches ^a -----	8	10	12	14	16
Maximum allowable load, tons-----	16	24	30	36	42 ^b

b. Skin Friction. This value for safe load, which may govern for piles in soft formations, is obtained from data or test loads as follows:

(1) *Driving data.*

(a) Piles driven by drophammer:

$$P=\frac{2Wh}{s+1.0}$$

(b) Piles driven by single-acting steam hammer:

$$P=\frac{2Wh}{s+0.1} \text{ (} t=\text{stroke of ram in feet)}$$

(c) Piles driven by double-acting steam hammer:

$$P=\frac{2E}{s+0.1}$$

Where *P*=safe load in pounds per pile

W=weight of drophammer or ram

h=fall of drophammer in feet or stroke of ram in inches

s=average penetration in inches per blow for the last 6 blows of drophammer or 20 blows of steam hammer

E=driving energy in foot-pounds per blow of double-acting hammer, estimated as follows:

<i>Weight of hammer (pounds)</i>	<i>Strokes per minute</i>	<i>Energy in foot-pounds per blow</i>
5,000-----	225	4, 150
	195	3, 720
	170	3, 280
7,000-----	145	8, 750
	140	8, 100
	135	7, 500
	130	6, 800

(2) *Test loads.* Normally test loads are increased 5 tons at 48-hour intervals. The maximum safe load per pile is one-half the load which in 48 hours produces settlement of ½ inch, not counting any settlement produced during and immediately after applying the increment.

c. Column Action. Piles with considerable unsupported length or with eccentric or lateral loads may require design as columns partially

^a Measured at a point one-third the length of the pile from the butt.

^b Obtainable only with the heaviest military driving equipment.

fixed at one end, using formulas given in chapter 9. The fixation must be estimated. It may be high or, as for piles bearing on rock with light overburden, very low.

224. Conversion Factors

Table 242. Conversion Factors

Multiply	by	to obtain
Aeres-----	43,560	square feet.
aeres-----	4,047	square meters.
acres-----	1.562×10^{-3}	square miles.
acres-----	5645.38	square varas.
aeres-----	4,840	square yards.
acre-feet-----	43,560	eubic-feet.
ares-----	0.02471	acres.
ares-----	100	square meters.
atmospheres-----	76.0	cms. of mercury.
atmospheres-----	29.92	inches of mercury.
atmospheres-----	33.90	feet of water.
atmospheres-----	10,333	kgs. per square meter.
atmospheres-----	14.70	pounds per sq. inch.
atmospheres-----	1.058	tons per sq. foot.
Bars-----	9.870×10^{-7}	atmospheres.
bars-----	1	dynes per sq. cm.
bars-----	0.01020	kgs. per square meter
bars-----	2.089×10^{-3}	pounds per sq. foot.
bars-----	1.450×10^{-5}	pounds per sq. inch.
board-feet-----	144 sq. in. $\times$ 1 in.	cubic inches.
British thermal units-----	0.2520	kilogram-calories.
British thermal units-----	777.5	foot-pounds.
British thermal units-----	3.927×10^{-4}	horse-power-hours.
British thermal units-----	1.054	joules.
British thermal units-----	107.5	kilogram-meters.
British thermal units-----	2.928×10^{-4}	kilowatt-hours.
B.t.u. per min-----	12.96	foot-pounds per sec.
B.t.u. per min-----	0.02356	horse-power.
B.t.u. per min-----	0.01757	kilowatts.
B.t.u. per min-----	17.57	watts.
B.t.u. per sq. ft. per min-----	0.1220	watts per square inch.
bushels-----	1.244	eubic feet.
bushels-----	2,150	eubic inches.
bushels-----	0.03524	eubic meters.
bushels-----	4	pecks.
bushels-----	64	pints (dry).
bushels-----	32	quarts (dry).
Centares-----	1	square meters.
centigrams-----	0101	grams.
centiliters-----	0.01	liters.
centimeters-----	0.3937	inches.
centimeters-----	0.01	meters.
centimeters-----	393.7	mils.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
centimeters	10	millimeters.
centimeters-dynes	1.020×10^{-3}	centimeter-grams.
centimeter-dynes	1.020×10^{-8}	meter-kilograms.
centimeter-dynes	7.376×10^{-8}	pound-feet.
centimeter-grams	980.7	centimeter-dynes.
centimeter-grams	10^{-5}	meter-kilograms.
centimeter-grams	7.233×10^{-5}	pound-feet.
centimeters of mercury	0.01316	atmospheres.
centimeters of mercury	0.4461	feet of water.
centimeters of mercury	136.0	kgs. per square meter.
centimeters of mercury	27.85	pounds per sq. foot.
centimeters of mercury	0.1934	pounds per sq. inch.
centimeters per second	1.969	feet per minute.
centimeters per second	0.03281	feet per second.
centimeters per second	0.036	kilometers per hour.
centimeters per second	0.6	meters per minute.
centimeters per second	0.02237	miles per hour.
centimeters per second	3.728×10^{-4}	miles per minute.
cms. per sec. per sec.	0.03281	feet per sec. per sec.
cms. per sec. per sec.	0.036	kms. per hour per sec.
cms. per sec. per sec.	0.02237	miles per hour per sec.
circular mils	5.067×10^{-6}	square centimeters.
circular mils	7.854×10^{-7}	square inches.
circular mils	0.7854	square mils.
cord-feet	4 ft. $\times$ 4 ft. $\times$ 1 ft.	cubic feet.
cords	8 ft. $\times$ 4 ft. $\times$ 4 ft.	cubic feet.
cubic centimeters	3.531×10^{-5}	cubic feet.
cubic centimeters	6.102×10^{-2}	cubic inches.
cubic centimeters	10^{-6}	cubic meters.
cubic centimeters	1.308×10^{-6}	cubic yards.
cubic centimeters	2.642×10^{-4}	gallons.
cubic centimeters	10^{-3}	liters.
cubic centimeters	2.113×10^{-3}	pints (liq.)
cubic centimeters	1.057×10^{-3}	quarts (liq.)
cubic feet	2.832×10^4	cubic cms.
cubic feet	1,728	cubic inches.
cubic feet	0.02832	cubic meters.
cubic feet	0.03704	cubic yards.
cubic feet	7.481	gallons.
cubic feet	28.32	liters.
cubic feet	59.84	pints (liq.).
cubic feet	29.92	quarts (liq.).
cubic feet per minute	472.0	cubic cms. per sec.
cubic feet per minute	0.1247	gallons per sec.
cubic feet per minute	0.4720	liters per second.
cubic feet per minute	62.4	lbs. of water per min.
cubic inches	16.39	cubic centimeters.
cubic inches	5.787×10^{-4}	cubic feet.
cubic inches	1.639×10^{-5}	cubic meters.
cubic inches	2.143×10^{-5}	cubic yards.
cubic inches	4.329×10^{-3}	gallons.

Table 242. . . Conversion Factors—Continued

Multiply	by	to obtain
cubic inches.....	1.639×10^{-2}	liters.
cubic inches.....	0.03463	pints (liq.).
cubic inches.....	0.01732	quarts (liq.).
cubic meters.....	10^6	cubic centimeters.
cubic meters.....	35.31	cubic feet.
cubic meters.....	61,023	cubic inches.
cubic meters.....	1.308	cubic yards.
cubic meters.....	264.2	gallons.
cubic meters.....	10^3	liters.
cubic meters.....	2113	pints (liq.).
cubic meters.....	1057	quarts (liq.).
cubic yards.....	7.646×10^5	cubic centimeters.
cubic yards.....	27	cubic feet.
cubic yards.....	46,656	cubic inches.
cubic yards.....	0.7646	cubic meters.
cubic yards.....	202.0	gallons.
cubic yards.....	764.6	liters.
cubic yards.....	1616	pints (liq.).
cubic yards.....	807.9	quarts (liq.).
cubic yards per minute.....	0.45	cubic feet per second.
cubic yards per minute.....	3.367	gallons per second.
cubic yards per minute.....	12.74	liters per second.
Days.....	24	hours.
days.....	1440	minutes.
days.....	86,400	seconds.
decigrams.....	0.1	grams.
deciliters.....	0.1	liters.
decimeters.....	0.1	meters.
degrees (angle).....	60	minutes.
degrees (angle).....	0.01745	radians.
degrees (angle).....	3600	seconds.
degrees per second.....	0.01745	radians per second.
degrees per second.....	0.1667	revolutions per min.
degrees per second.....	0.002778	revolutions per sec.
dekagrams.....	10	grams.
dekaliters.....	10	liters.
dekameters.....	10	meters.
drams.....	1.772	grams.
drams.....	0.0625	ounces.
dynes.....	1.020×10^{-3}	grams.
dynes.....	7.233×10^{-5}	poundals.
dynes.....	2.248×10^{-6}	pounds.
dynes per square cm.....	1	bars.
Ergs.....	9.486×10^{-11}	British thermal units.
ergs.....	1	dyne-centimeters.
ergs.....	7.376×10^{-8}	foot-pounds.
ergs.....	1.020×10^{-3}	gram-centimeters.
ergs.....	10^{-7}	joules.
ergs.....	2.390×10^{-11}	kilogram-calories.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
ergs-----	1.020×10^{-8}	kilogram-meters.
ergs per second-----	5.692×10^{-9}	B.t. units per minute.
ergs per second-----	4.426×10^{-6}	foot-pounds per minute.
ergs per second-----	7.376×10^{-8}	foot-pounds per second.
ergs per second-----	1.341×10^{-10}	horse-power.
ergs per second-----	1.434×10^{-9}	kg.-calories per minute.
ergs per second-----	10^{-10}	kilowatts.
Fathoms-----	6	feet.
feet-----	30.48	centimeters.
feet-----	12	inches.
feet-----	0.3048	meters.
feet-----	.36	varas.
feet-----	$\frac{1}{3}$	yards.
feet of water-----	0.02950	atmospheres.
feet of water-----	0.8826	inches of mercury.
feet of water-----	304.8	kgs. per square meter.
feet of water-----	62.43	pounds per sq. ft.
feet of water-----	0.4335	pounds per sq. inch.
feet per minute-----	0.5080	centimeters per sec.
feet per minute-----	0.01667	feet per second.
feet per minute-----	0.01829	kilometers per hour.
feet per minute-----	0.3048	meters per minute.
feet per minute-----	0.01136	miles per hour.
feet per second-----	30.48	centimeters per sec.
feet per second-----	1.097	kilometers per hour.
feet per second-----	0.5921	knots per hour.
feet per second-----	18.29	meters per minute.
feet per second-----	0.6818	miles per hour.
feet per second-----	0.01136	miles per minute.
feet per 100 feet-----	1	per cent grade.
feet per sec. per sec-----	30.48	cms. per sec. per sec.
feet per sec. per sec-----	1.097	kms. per hr. per sec.
feet per sec. per sec-----	0.3048	meters per sec. per sec.
feet per sec. per sec-----	0.6818	miles per hr. per sec.
foot-pounds-----	1.286×10^{-3}	British thermal units.
foot-pounds-----	1.356×10^7	ergs.
foot-pounds-----	5.050×10^{-7}	horse-power-hours.
foot-pounds-----	1.356	joules.
foot-pounds-----	3.241×10^{-4}	kilogram-calories.
foot-pounds-----	0.1383	kilogram-meters.
foot-pounds-----	3.766×10^{-7}	kilowatt-hours.
foot-pounds per minute-----	1.286×10^{-3}	B.t. units per minute.
foot-pounds per minute-----	0.01667	foot-pounds per sec.
foot-pounds per minute-----	3.030×10^{-5}	horse-power.
foot-pounds per minute-----	3.241×10^{-4}	kg.-calories per min.
foot-pounds per minute-----	2.260×10^{-5}	kilowatts.
foot-pounds per second-----	7.717×10^{-2}	B.t. units per minute.
foot-pounds per second-----	1.818×10^{-3}	horse-power.
foot-pounds per second-----	1.945×10^{-2}	kg.-calories per min.
foot-pounds per second-----	1.356×10^{-3}	kilowatts.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
furlongs.....	40	rods.
Gallons.....	3785	cubic centimeters.
gallons.....	0.1337	cubic feet.
gallons.....	231	cubic inches.
gallons.....	3.785×10^{-3}	cubic meters.
gallons.....	4.951×10^{-3}	cubic yards.
gallons.....	3.785	liters.
gallons.....	8	pints (liq.).
gallons.....	4	quarts (liq.).
gallons per minute.....	2.228×10^{-3}	cubic feet per second.
gallons per minute.....	0.06308	liters per second.
gills.....	0.1183	liters.
gills.....	0.25	pints (liq.).
grains (troy).....	1	grains (av.).
grains (troy).....	0.06480	grams.
grains (troy).....	0.04167	pennyweights (troy).
grams.....	980.7	dynes.
grams.....	15.43	grains (troy).
grams.....	10^{-3}	kilograms.
grams.....	10^3	milligrams.
grams.....	0.03527	ounces.
grams.....	0.03215	ounces (troy).
grams.....	0.07093	poundals.
grams.....	2.205×10^{-3}	pounds.
gram-calories.....	3.968×10^{-3}	British thermal units.
gram-centimeters.....	9.302×10^{-3}	British thermal units.
gram-centimeters.....	980.7	ergs.
gram-centimeters.....	7.233×10^{-3}	foot-pounds.
gram-centimeters.....	9.807×10^{-5}	joules.
gram-centimeters.....	2.344×10^{-8}	kilogram-calories.
gram-centimeters.....	10^{-5}	kilogram-meters.
grams per cm.....	5.600×10^{-3}	pounds per inch.
grams per cu. cm.....	62.43	pounds per cubic foot.
grams per cu. cm.....	0.03613	pounds per cubic inch.
grams per cu. cm.....	3.405×10^{-7}	pounds per mil-foot.
Hectares.....	2.471	acres.
hectares.....	1.076×10^5	square feet.
hectograms.....	100	grams.
hectoliters.....	100	liters.
hectometers.....	100	meters.
hectowatts.....	100	watts.
hemispheres (sol. angle).....	0.5	sphere.
hemispheres (sol. angle).....	4	spherical right angles.
hemispheres (sol. angle).....	6.283	steradians.
horse-power.....	42.44	B.t. units per min.
horse-power.....	33,000	foot-pounds per min.
horse-power.....	550	foot-pounds per sec.
horse-power.....	1.014	horse-power (metric).
horse-power.....	10.70	kg.-calories per min.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
horse-power.....	0.7457	kilowatts.
horse-power.....	745.7	watts.
horse-power (boiler).....	33,520	B.t.u. per hour.
horse-power (boiler).....	9.804	kilowatts.
horse-power-hours.....	2547	British thermal units.
horse-power-hours.....	1.98×10^6	foot-pounds.
horse-power-hours.....	2.684×10^6	joules.
horse-power-hours.....	641.7	kilogram-calories.
horse-power-hours.....	2.737×10^5	kilogram-meters.
horse-power-hours.....	0.7457	kilowatt-hours.
hours.....	60	minutes.
hours.....	3600	seconds.
Inches.....	2.540	centimeters.
inches.....	10^3	mils.
inches.....	.03	varas.
inches of mercury.....	0.03342	atmospheres.
inches of mercury.....	1.133	feet of water.
inches of mercury.....	345.3	kgs. per square meter.
inches of mercury.....	70.73	pounds per square ft.
inches of mercury.....	0.4912	pounds per square in.
inches of water.....	0.002458	atmospheres.
inches of water.....	0.07355	inches of mercury.
inches of water.....	25.40	kgs. per square meter.
inches of water.....	0.5781	ounces per square in.
inches of water.....	5.204	pounds per square ft.
inches of water.....	0.03613	pounds per square in.
Joules.....	9.486×10^{-4}	British thermal units.
joules.....	10^7	ergs.
joules.....	0.7376	foot-pounds.
joules.....	2.390×10^{-4}	kilogram-calories.
joules.....	0.1020	kilogram-meters.
joules.....	2.778×10^{-4}	watt-hours.
Kilograms.....	980,665	dynes.
kilograms.....	10^3	grams.
kilograms.....	70.93	poundals.
kilograms.....	2.2046	pounds.
kilograms.....	1.102×10^{-3}	tons (short).
kilogram-calories.....	3.968	British thermal units.
kilogram-calories.....	3088	foot-pounds.
kilogram-calories.....	1.588×10^{-3}	horse-power-hours.
kilogram-calories.....	4183	joules.
kilogram-calories.....	426.6	kilogram-meters.
kilogram-calories.....	1.162×10^{-3}	kilowatt-hours.
kg.-calories per min.....	51.43	foot-pounds per sec.
kg.-calories per min.....	0.09351	horse-power.
kg.-calories per min.....	0.06972	kilowatts.
kgs.-cms. squared.....	2.373×10^{-3}	pounds-feet squared.
kgs.-cms. squared.....	0.3417	pounds-inches squared.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
kilogram-meters	9.302×10^{-3}	British thermal units.
kilogram-meters	9.807×10^7	ergs.
kilogram-meters	7.233	foot-pounds.
kilogram-meters	9.807	joules.
kilogram-meters	2.344×10^{-3}	kilogram-calories.
kilogram-meters	2.724×10^{-6}	kilowatt-hours.
kgs. per cubic meter	10^{-3}	grams per cubic cm.
kgs. per cubic meter	0.06243	pounds per cubic foot.
kgs. per cubic meter	3.613×10^{-6}	pounds per cubic inch.
kgs. per cubic meter	3.405×10^{-10}	pounds per mil. foot.
kgs. per meter	0.6720	pounds per foot.
kgs. per square meter	9.678×10^{-5}	atmospheres.
kgs. per square meter	98.07	bars.
kgs. per square meter	3.281×10^{-3}	feet of water.
kgs. per square meter	2.896×10^{-3}	inches of mercury.
kgs. per square meter	0.2048	pounds per square ft.
kgs. per square meter	1.422×10^{-3}	pounds per square in.
kgs. per sq. millimeter	10^6	kgs. per square meter.
kilolines	10^3	maxwells.
kiloliters	10^3	liters.
kilometers	10^5	centimeters.
kilometers	3281	feet.
kilometers	10^3	meters.
kilometers	0.6214	miles.
kilometers	1093.6	yards.
kilometers per hour	27.78	centimeters per sec.
kilometers per hour	54.68	feet per minute.
kilometers per hour	0.9113	feet per second.
kilometers per hour	0.5396	knots per hour.
kilometers per hour	16.67	meters per minute.
kilometers per hour	0.6214	miles per hour.
kms. per hour per sec	27.78	cms. per sec. per sec.
kms. per hour per sec	0.9113	ft. per sec. per sec.
kms. per hour per sec	0.2778	meters per sec. per sec.
kms. per hour per sec	0.6214	miles per hr. per sec.
kilometers per min	60	kilometers per hour.
kilowatts	56.92	B.t. units per min.
kilowatts	4.425×10^4	foot-pounds per min.
kilowatts	737.6	foot-pounds per sec.
kilowatts	1.341	horse-power.
kilowatts	14.34	kg.-calories per min.
kilowatts	10^3	watts.
kilowatt-hours	3415	British thermal units.
kilowatt-hours	2.655×10^6	foot-pounds.
kilowatt-hours	1.341	horse-power-hours.
kilowatt-hours	3.6×10^6	joules.
kilowatt-hours	860.5	kilogram-calories.
kilowatt-hours	3.671×10^5	kilogram-meters.
knots	51.48	centimeters per sec.
knots	1.689	feet per second.
knots	1.853	kilometers per hour.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
knots -----	1.152	miles per hour.
Links (engineer's) -----	12	inches.
links (surveyor's) -----	7.92	inches.
liters -----	10^3	cubic centimeters.
liters -----	0.03531	cubic feet.
liters -----	61.02	cubic inches.
liters -----	10^{-3}	cubic meters.
liters -----	1.308×10^{-3}	cubic yards.
liters -----	0.2642	gallons.
liters -----	2.113	pints (liq.).
liters -----	1.057	quarts (liq.).
liters per minute -----	5.885×10^{-4}	cubic feet per second.
liters per minute -----	4.403×10^{-3}	gallons per second.
$\log_{10} N$ -----	2.303	$\log e N$ or $\ln N$.
$\log e N$ or $\ln N$ -----	0.4343	$\log_{10} N$.
lumens per sq. ft. -----	1	foot-candles.
Meters -----	100	centimeters.
meters -----	3.2808	feet.
meters -----	39.37	inches.
meters -----	10^{-3}	kilometers.
meters -----	10^3	millimeters.
meters -----	1.0936	yards.
meter-kilograms -----	9.807×10^7	centimeter-dynes.
meter-kilograms -----	10^5	centimeter-grams.
meter-kilograms -----	7.233	pound-feet.
meters per minute -----	1.667	centimeters per sec.
meters per minute -----	3.281	feet per minute.
meters per minute -----	0.05468	feet per second.
meters per minute -----	0.06	kilometers per hour.
meters per minute -----	0.03728	miles per hour.
meters per second -----	196.8	feet per minute.
meters per second -----	3.281	feet per second.
meters per second -----	3.6	kilometers per hour.
meters per second -----	0.06	kilometers per min.
meters per second -----	2.237	miles per hour.
meters per second -----	0.03728	miles per minute.
meters per sec. per sec. -----	3.281	feet per sec. per sec.
meters per sec. per sec. -----	3.6	kms. per hour per sec.
meters per sec. per sec. -----	2.237	miles per hour per sec.
microns -----	10^{-6}	meters.
miles -----	1.609×10^5	centimeters.
miles -----	5280	feet.
miles -----	1.6093	kilometers.
miles -----	1760	yards.
miles -----	1900.8	varas.
miles per hour -----	44.70	centimeters per sec.
miles per hour -----	88	feet per minute.
miles per hour -----	1.467	feet per second.
miles per hour -----	1.6093	kilometers per hour.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
miles per hour.....	0.8684	knots per hour.
miles per hour.....	26.82	meters per minute.
miles per hour per sec.....	44.70	cms. per sec. per sec.
miles per hour per sec.....	1.467	feet per sec. per sec.
miles per hour per sec.....	1.6093	kms. per hour per sec.
miles per hour per sec.....	0.4470	M. per sec. per sec.
miles per minute.....	2682	centimeters per sec.
miles per minute.....	88	feet per second.
miles per minute.....	1.6093	kilometers per min.
miles per minute.....	0.8684	knots per minute.
miles per minute.....	60	miles per hour.
milliers.....	10^3	kilograms.
milligrams.....	10^{-3}	grams.
milliliters.....	10^{-3}	liters.
millimeters.....	0.1	centimeters.
millimeters.....	0.03937	inches.
millimeters.....	39.37	mils.
mils.....	0.002540	centimeters.
mils.....	10^{-3}	inches.
miner's inches.....	1.5	cubic feet per min.
minutes (angle).....	2.909×10^{-4}	radians.
minutes (angle).....	60	seconds (angle).
months.....	30.42	days.
months.....	730	hours.
months.....	43,800	minutes.
months.....	2.628×10^6	seconds.
myriagrams.....	10	kilograms.
myriameters.....	10	kilometers.
myriawatts.....	10	kilowatts.
Nautical miles.....	6080	feet.
nautical miles.....	1.853	kilometers.
nautical miles.....	1.152	miles.
nautical miles.....	2027	yards.
Ounces.....	8	drams.
ounces.....	437.5	grains.
ounces.....	28.35	grams.
ounces.....	0.0625	pounds.
ounces (fluid).....	1.805	cubic inches.
ounces (fluid).....	0.02957	liters.
ounces (troy).....	480	grains (troy).
ounces (troy).....	31.10	grams.
ounces (troy).....	20	pennyweights (troy).
ounces (troy).....	0.08333	pounds (troy).
ounces per square inch.....	0.0625	pounds per sq. inch.
Pennyweights (troy).....	24	grains (troy).
pennyweights (troy).....	1.555	grams.
pennyweights (troy).....	0.05	ounces (troy).
perches (masonry).....	24.75	cubic feet.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
pints (dry).....	33.60	cubic inches.
pints (liq.).....	28.87	cubic inches.
poundals.....	13,826	dynes.
poundals.....	14.10	grams.
poundals.....	0.03108	pounds.
pounds.....	444,823	dynes.
pounds.....	7000	grains.
pounds.....	453.6	grams.
pounds.....	16	ounces.
pounds.....	32.17	poundals.
pounds (troy).....	0.8229	pounds (av.).
pound-feet.....	1.356×10^7	centimeter-dynes.
pound-feet.....	13,825	centimeter-grams.
pound-feet.....	0.1383	meter-kilograms.
pound-feet squared.....	421.3	kgs.-cms. squared.
pounds-feet squared.....	144	pounds-ins. squared.
pounds-inches squared.....	2.926	kgs.-cms. squared.
pounds-inches squared.....	6.945×10^{-3}	pounds-feet squared.
pounds of water.....	0.01602	cubic feet.
pounds of water.....	27.68	cubic inches.
pounds of water.....	0.1198	gallons.
pounds of water per min.....	2.669×10^{-4}	cubic feet per sec.
pounds per cubic foot.....	0.01602	grams per cubic cm.
pounds per cubic foot.....	16.02	kgs. per cubic meter.
pounds per cubic foot.....	5.787×10^{-4}	pounds per cubic inch.
pounds per cubic foot.....	5.456×10^{-9}	pounds per mil foot.
pounds per cubic inch.....	27.68	pounds per cubic cm.
pounds per cubic inch.....	2.768×10^4	kgs. per cubic meter.
pounds per cubic inch.....	1728	pounds per cubic foot.
pounds per cubic inch.....	9.425×10^{-6}	pounds per mil foot.
pounds per foot.....	1.488	kgs. per meter.
pounds per inch.....	178.6	grams per cm.
pounds per mil foot.....	2.306×10^6	grams per cubic cm.
pounds per square foot.....	0.01602	feet of water.
pounds per square foot.....	4.882	kgs. per square meter.
pounds per square foot.....	6.944×10^{-3}	pounds per sq. inch.
pounds per square inch.....	0.06804	atmospheres.
pounds per square inch.....	2.307	feet of water.
pounds per square inch.....	2.036	inches of mercury.
pounds per square inch.....	703.1	kgs. per square meter.
pounds per square inch.....	144	pounds per sq. foot.
Quadrants (angle).....	90	degrees.
quadrants (angle).....	5400	minutes.
quadrants (angle).....	1.571	radians.
quarts (dry).....	67.20	cubic inches.
quarts (liq.).....	57.75	cubic inches.
quintals.....	100	pounds.
quires.....	25	sheets.
Radians.....	57.30	degrees.
radians.....	3438	minutes.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
radians.....	0.637	quadrants.
radians per second.....	57.30	degrees per second.
radians per second.....	0.1592	revolutions per sec.
radians per second.....	9.549	revolutions per min.
radians per sec. per sec.....	573.0	revs. per min. per min.
radians per sec. per sec.....	9.549	revs. per min. per sec.
radians per sec. per sec.....	0.1592	revs. per sec. per sec.
reams.....	500	sheets.
revolutions.....	360	degrees.
revolutions.....	4	quadrants.
revolutions.....	6.283	radians.
revolutions per minute.....	6	degrees per second.
revolutions per minute.....	0.1047	radians per second.
revolutions per minute.....	0.01667	revolutions per sec.
revs. per min. per min.....	1.745×10^{-3}	rad. per sec. per sec.
revs. per min. per min.....	0.01667	revs. per min. per sec.
revs. per min. per min.....	2.778×10^{-4}	revs. per sec. per sec.
revolutions per second.....	360	degrees per second.
revolutions per second.....	6.283	radians per second.
revolutions per second.....	60	revs. per minute.
revs. per sec. per sec.....	6.283	rad. per sec. per sec.
revs. per sec. per sec.....	3600	revs. per min. per min.
revs. per sec. per sec.....	60	revs. per min. per sec.
rods.....	16.5	feet.
Seconds (angle).....	4.848×10^{-6}	radians.
spheres (solid angle).....	12.57	steradians.
spherical right angles.....	0.25	hemispheres.
spherical right angles.....	0.125	spheres.
spherical right angles.....	1.571	steradians.
square centimeters.....	1.973×10^5	circular mils.
square centimeters.....	1.076×10^{-3}	square feet.
square centimeters.....	0.1550	square inches.
square centimeters.....	10^{-6}	square meters.
square centimeters.....	100	square millimeters.
square feet.....	2.296×10^{-5}	acres.
square feet.....	929.0	square centimeters.
square feet.....	144	square inches.
square feet.....	0.09290	square meters.
square feet.....	3.587×10^{-8}	square miles.
square feet.....	.1296	square varas.
square feet.....	1/9	square yards.
sq. feet-feet sqd.....	2.074×10^4	sq. inches-inches sqd.
square inches.....	1.273×10^6	circular mils.
square inches.....	6.452	square centimeters.
square inches.....	6.944×10^{-3}	square feet.
square inches.....	10^6	square mils.
square inches.....	645.2	square millimeters.
sq. inches-inches sqd.....	41.62	sq. cms.-cms. sqd.
sq. inches-inches sqd.....	4.823×10^{-5}	sq. feet-feet sqd.
square kilometers.....	247.1	acres.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
square kilometers.....	10.76×10^6	square feet.
square kilometers.....	10^6	square meters.
square kilometers.....	0.3861	square miles.
square kilometers.....	1.196×10^6	square yards.
square meters.....	2.471×10^{-4}	acres.
square meters.....	10.764	square feet.
square meters.....	3.861×10^{-7}	square miles.
square meters.....	1.196	square yards.
square miles.....	640	acres.
square miles.....	27.88×10^6	square feet.
square miles.....	2.590	square kilometers.
square miles.....	3.613,040.45	square varas.
square miles.....	3.098×10^6	square yards.
square millimeters.....	1.973×10^3	circular mils.
square millimeters.....	0.01	square centimeters.
square millimeters.....	1.550×10^{-3}	square inches.
square mils.....	1.273	circular mils.
square mils.....	6.452×10^{-6}	square centimeters.
square mils.....	10^{-6}	square inches.
square varas.....	.0001771	acres.
square varas.....	7.716049	square feet.
square varas.....	.0000002765	square miles.
square varas.....	.857339	square yards.
square yards.....	2.066×10^{-4}	acres.
square yards.....	9	square feet.
square yards.....	0.8361	square meters.
square yards.....	3.228×10^{-7}	square miles.
square yards.....	1.1664	square varas.
steradians.....	0.1592	hemispheres.
steradians.....	0.07958	spheres.
steradians.....	0.6366	spherical right angles.
steres.....	10^3	liters.
Temp. (deg. C.) + 273.....	1	abs. temp. (deg. C.).
temp. (deg. C.) + 17.8.....	1.8	temp. (deg. Fahr.).
temp. (deg. F.) + 460.....	1	abs. temp. (deg. F.).
temp. (deg. F.) - 32.....	5/9	temp. (deg. Cent.).
tons (long).....	1016	kilograms.
tons (long).....	2240	pounds.
tons (metric).....	10^3	kilograms.
tons (metric).....	2205	pounds.
tons (short).....	907.2	kilograms.
tons (short).....	2000	pounds.
tons (short) per sq. ft.....	9765	kgs. per square meter.
tons (short) per sq. ft.....	13.89	pounds per sq. inch.
tons (short) per sq. in.....	1.406×10^6	kgs. per square meter.
tons (short) per sq. in.....	2000	pounds per sq. inch.
Varas.....	2.7777	feet.
varas.....	33.3333	inches.
varas.....	.000526	miles.

Table 242. Conversion Factors—Continued

Multiply	by	to obtain
varas.....	.9259	yards.
Watts.....	0.05692	B.t. units per min.
watts.....	10^7	ergs per second.
watts.....	44.26	foot-pounds per min.
watts.....	0.7376	foot-pounds per sec.
watts.....	1.341×10^{-3}	horse-power.
watts.....	0.01434	kg.-calories per min.
watts.....	10^2	kilowatts.
watt-hours.....	3.415	British thermal units.
watt-hours.....	2655	foot-pounds.
watt-hours.....	1.341×10^{-3}	horse-power-hours.
watt-hours.....	0.8605	kilogram-calories.
watt-hours.....	367.1	kilogram-meters.
watt-hours.....	10^{-3}	kilowatt-hours.
webers.....	10^8	maxwells.
weeks.....	168	hours.
weeks.....	10,080	minutes.
weeks.....	604,800	seconds.
Yards.....	91.44	centimeters.
yards.....	3	feet.
yards.....	36	inches.
yards.....	0.9144	meters.
yards.....	1.08	varas.
years (common).....	365	days.
years (common).....	8760	hours.
years (leap).....	366	days.
years (leap).....	8784	hours.

225. Twenty-Year Calendar

The calendar for each month from 1956 to 1975 is shown in figure 111.

	JAN 31 DAYS	FEB 28 DAYS	MAR 31 DAYS	APR 30 DAYS	MAY 31 DAYS	JUNE 30 DAYS	JULY 31 DAYS	AUG 31 DAYS	SEPT 30 DAYS	OCT 31 DAYS	NOV 30 DAYS	DEC 31 DAYS
1956	A	D*	E	A	C	F	A	D	G	B	E	G
1957	C	F	F	B	D	G	B	E	A	C	F	A
1958	D	G	G	C	E	A	C	F	B	D	G	B
1959	E	A	A	D	F	B	D	G	C	E	A	C
1960	F	B*	C	F	A	D	F	B	E	G	C	E
1961	A	D	D	G	B	E	G	C	F	A	D	F
1962	B	E	E	A	C	F	A	D	G	B	E	G
1963	C	F	F	B	D	G	B	E	A	C	F	A
1964	D	G*	A	D	F	B	D	G	C	E	A	C
1965	F	B	B	E	G	C	F	A	D	F	B	D
1966	G	C	C	F	A	D	F	B	E	G	C	E
1967	A	D	D	G	B	E	G	C	F	A	D	F
1968	B	E*	F	B	D	G	B	E	A	C	F	A
1969	D	G	G	C	E	A	C	F	B	D	G	B
1970	E	A	A	D	F	B	D	G	C	E	A	C
1971	F	B	B	E	G	C	E	A	D	F	B	D
1972	G	C	D	G	B	E	G	C	F	A	D	F
1973	B	E	E	A	C	F	A	D	G	B	E	G
1974	C	F	F	B	D	G	B	E	A	C	F	A
1975	D	G	G	C	E	A	C	F	B	D	G	B

* LEAP YEARS FEBRUARY HAS 29 DAYS

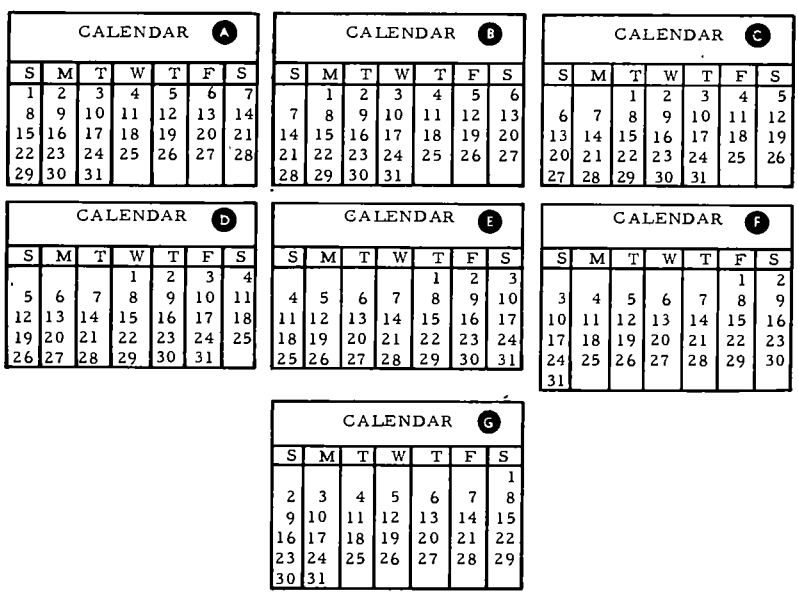


Figure 111. Twenty-year calendar.

226. Table of Days Between Two Dates

Table 243 shows the elapsed time in days between two dates, inclusive of both the initial and the terminal date.

Note. For a leap year add one day after 28 February.

Table 243. *Elapsed Days*

Day	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1-----	1	32	60	91	121	152	182	213	244	274	305	335
2-----	2	33	61	92	122	153	183	214	245	275	306	336
3-----	3	34	62	93	123	154	184	215	246	276	307	337
4-----	4	35	63	94	124	155	185	216	247	277	308	338
5-----	5	36	64	95	125	156	186	217	248	278	309	339
6-----	6	37	65	96	126	157	187	218	249	279	310	340
7-----	7	38	66	97	127	158	188	219	250	280	311	341
8-----	8	39	67	98	128	159	189	220	251	281	312	342
9-----	9	40	68	99	129	160	190	221	252	282	313	343
10-----	10	41	69	100	130	161	191	222	253	283	314	344
11-----	11	42	70	101	131	162	192	223	254	284	315	345
12-----	12	43	71	102	132	163	193	224	255	285	316	346
13-----	13	44	72	103	133	164	194	225	256	286	317	347
14-----	14	45	73	104	134	165	195	226	257	287	318	348
15-----	15	46	74	105	135	166	196	227	258	288	319	349
16-----	16	47	75	106	136	167	197	228	259	289	320	350
17-----	17	48	76	107	137	168	198	229	260	290	321	351
18-----	18	49	77	108	138	169	199	230	261	291	322	352
19-----	19	50	78	109	139	170	200	231	262	292	323	353
20-----	20	51	79	110	140	171	201	232	263	293	324	354
21-----	21	52	80	111	141	172	202	233	264	294	325	355
22-----	22	53	81	112	142	173	203	234	265	295	326	356
23-----	23	54	82	113	143	174	204	235	266	296	327	357
24-----	24	55	83	114	144	175	205	236	267	297	328	358
25-----	25	56	84	115	145	176	206	237	268	298	329	359
26-----	26	57	85	116	146	177	207	238	269	299	330	360
27-----	27	58	86	117	147	178	208	239	270	300	331	361
28-----	28	59	87	118	148	179	209	240	271	301	332	362
29-----	29	-----	88	119	149	180	210	241	272	302	333	363
30-----	30	-----	89	120	150	181	211	242	273	303	334	364
31-----	31	-----	90	-----	151	-----	212	243	-----	304	-----	365

Table 243. *Elapsed Days*—Continued

Day	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1-----	366	397	425	456	486	517	547	578	609	639	670	700
2-----	367	398	426	457	487	518	548	579	610	640	671	701
3-----	368	399	427	458	488	519	549	580	611	641	672	702
4-----	369	400	428	459	489	520	550	581	612	642	673	703
5-----	370	401	429	460	490	521	551	582	613	643	674	704
6-----	371	402	430	461	491	522	552	583	614	644	675	705
7-----	372	403	431	462	492	523	553	584	615	645	676	706
8-----	373	404	432	463	493	524	554	585	616	646	677	707
9-----	374	405	433	464	494	525	555	586	617	647	678	708
10-----	375	406	434	465	495	526	556	587	618	648	679	709
11-----	376	407	435	466	496	527	557	588	619	649	680	710
12-----	377	408	436	467	497	528	558	589	620	650	681	711
13-----	378	409	437	468	498	529	559	590	621	651	682	712
14-----	379	410	438	469	499	530	560	591	622	652	683	713
15-----	380	411	439	470	500	531	561	592	623	653	684	714
16-----	381	412	440	471	501	532	562	593	624	654	685	715
17-----	382	413	441	472	502	533	563	594	625	655	686	716
18-----	383	414	442	473	503	534	564	595	626	656	687	717
19-----	384	415	443	474	504	535	565	596	627	657	688	718
20-----	385	416	444	475	505	536	566	597	628	658	689	719
21-----	386	417	445	476	506	537	567	598	629	659	690	720
22-----	387	418	446	477	507	538	568	599	630	660	691	721
23-----	388	419	447	478	508	539	569	600	631	661	692	722
24-----	389	420	448	479	509	540	570	601	632	662	693	723
25-----	390	421	449	480	510	541	571	602	633	663	694	724
26-----	391	422	450	481	511	542	572	603	634	664	695	725
27-----	392	423	451	482	512	543	573	604	635	665	696	726
28-----	393	424	452	483	513	544	574	605	636	667	697	727
29-----	394	-----	453	484	514	545	575	606	637	666	698	728
30-----	395	-----	454	485	515	546	576	607	638	668	699	729
31-----	396	-----	455	-----	516	-----	577	608	-----	669	-----	730

227. Hours of Daylight

Table 244. Hours of Daylight¹

Latitude north ²	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0°-----	12	12	12	12	12	12	12	12	12	12	12	12
10°-----	12	12	12	12	13	13	13	12	12	12	12	12
20°-----	11	12	12	13	13	13	13	13	12	12	11	11
30°-----	10	11	12	13	14	14	14	13	12	11	11	10
40°-----	10	11	12	13	14	15	15	14	12	11	10	9
50°-----	9	10	12	14	15	16	16	14	12	11	9	8
60°-----	7	9	12	15	17	19	18	16	12	10	8	6
70°-----	0	7	12	16	23	24	24	18	12	9	4	0
80°-----	0	0	12	24	24	24	24	24	12	5	0	0

¹ Time between sunrise and sunset. Approximately 30 minutes twilight is available before sunrise and after sunset.

² For latitude south, subtract figure given from 24.

228. Library Reference Sets for Engineer Units

Library reference sets for engineering units are listed below. Reference works are grouped by sets in table 245.

Set No.	Description
1	Celestial Navigation
2	Company
3	Heavy Shop Company
4	Maintenance Company
5	Regiment
6	Road Construction
7	Topographic Battalion, Headquarters and Service Company, Army
8	Topographic Battalion, Headquarters and Service Company, General Headquarters.
9	Topographic Battalion, Photomapping Company
10	Topographic Battalion, Reproduction Company
11	Topographic Battalion, Survey Company
12	Topographic Company, Aviation
13	Topographic Company, Corps
14	Water Supply Company
15	Forestry Operations

Table 245. Reference Works, Grouped by Subjects

Reference works	In library reference sets Nos.
Engineer's Handbooks:	
American Electricians' Handbook—Croft-----	3-5-7-8-9-12-13
Civil Engineers' Reference Book—Trautwine-----	2-5-15
Mechanical Engineer's Handbook—Marks-----	5-7-8-9
Mathematics and Science:	
Trigonometry—Kells, Kerns and Bland-----	8-9-12
Calculus, Differential and Integral—Granville-----	8

Table 245. Reference Works, Grouped by Subjects—Continued

Reference works	In library reference sets Nos.
Mathematics and Science—Continued	
Errors and Theory of Least Squares—Welds.....	8
Chemistry and Physics Handbook—Hodgman.....	7-10-12-14
Chemical Engineers' Handbook—Perry.....	14
Medicine, Military Preventive—Col Dunham.....	14
Tables, Cube and Square Roots—Barlow.....	7
Tables of Functions of Angles—Vega.....	7-8-9-11-12-13
Tables of Functions of Angles—Ives.....	7-8-9-11-12-13
Construction:	
Standard Construction Methods—Underwood.....	2
Building Construction Handbook (2 Vol)—Hool and Johnson.	5
Steel Construction Handbook—American Inst. of Steel Construction.	5
Asphalt Highway, Engineers' Pocket Reference Book....	6
Concrete Inspection Manual—American Concrete Inst...	6
Concrete Mixtures, Design and Control—Portland Cement Association.	6
Asphalt Construction Specifications—Asphalt Inst.....	6
Highway Engineers' Handbook—Harger and Bonney, Vol. 1.	5
Highway Design and Construction—Bruce.....	6
Military Roads in Forward Areas Occasional Papers No. 74, Nov. 41—The Engineer School.	6
Soil Cement Roads—Portland Cement Association.....	6
Soil Mechanics and Stabilization, Vol. 18, part 2, Highway Research Board, Washington.	6
Soil stabilization w/Asphalt Bulletin.....	6
Forestry:	
Logging—Bryant.....	15
Lumber, Its Manufacture and Distribution—Bryant....	15
Pub. No. 509, Operating Small Sawmills—U.S. Dept. of Agriculture.	15
Maintenance and Repairs:	
Arc Welding Instruction Course, Exercises.....	3-4
Arc Welding Instruction Courses, Lectures—Air Reduction Sales Co.	3-4
Automotive Construction and Repair Manual—F. L. Curfman Mfg. Co.	3
Drilling and Surfacing Practice—Colvin and Stanley....	3
Gear Cutting Practice—Colvin and Stanley.....	3
Machine Shop Technology, 6 parts—National Metal Trades Association.	3-4
Machine Shop Training Course, 2 Vol.—Franklin and Jones.	3
Machine Tools and Their Operation, 2 Parts—Colvin and Stanley.	3
American Machinists' Handbook—Colvin and Stanley---	3

Table 245. Reference Works, Grouped by Subjects—Continued

Reference works	In library reference sets Nos.
Maintenance and Repairs—Continued	.
Oxyacetylene Handbook, Revised—Linde Air Production Co.	3
Turning and Boring Practice—Colvin and Stanley.....	3
Welding and Cutting (Oxyacetylene) Lectures.....	3-4
Welding and Cutting (Oxyacetylene) Work Sheets—Air Reduction Sales Co.	3-4
Welding and Its Application—Rossi.....	3-4
Welding Design and Practice, Procedure—Lincoln Elec. Co.	3-4
Welding Encyclopedia—MacKenzie and H. S. Card.....	3
Surveying and Mapping:	
Almanac, American Air—Naval Observatory.....	1
Almanac, Nautical, and Ephemeris—Naval Observatory	1-7-8-12-13
Navigation and Nautical Astronomy—Dutton.....	1-7-8-13
Radio Time Signals—H.O. 205 Extract.....	1
American Practical Navigator—USN H.O. No. 9.....	1
Computer, Polaris, Azimuth and Altitude—USGS Polaroidal Jr.	1-7-8-11-12
Aero Photography and Aero Surveying—Bagley.....	7-12
Astronomy, Field—Hosmer.....	7-8-12
Geodesy—Ingram.....	7-8
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Grid System for Military Maps—Engr Repro Plant.....	8-9-10-12-13
Photogrammetry—Anderson.....	7
Photogrammetry, Aerial and Terrestrial—Talley.....	7-8-9-12-13
Photogrammetry, Manual of—Amer Soc of Photographers.	7-9-12-13
Photography, Elementary—Neblette, Brehm and Priest..	7-10-12-13
Photography, Theory and Practice of—Clere.....	7-12
Surveying, Vol. I—Breed and Hosmer.....	7-13-15
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Surveying Computations—HMSO.....	7
Pub. No. 43, Metric Computations of Position—USC and GS.	7-8-9-12
Tables, Manuals, Bulletins—USC and GS.....	7-8-9-11-12-13
Lithography, Basic—Litho Tech Fdn.....	10-12
Lithographers Manual—Soderstorm.....	10-12
Printing, Practice of—Polk.....	12
Albumen Photolithography—Litho Tech Fdn.....	12
Photolithography—Sayre.....	12-13
Water Supply:	
Hydraulics Handbook—King.....	14
Water, Analysis—A.W.W.A.....	14
Water, Quality and Treatment Manual—A.W.W.A.....	14
Water Supplies, Public—Turneure and Russel.....	14
Water Works Handbook—Flinn, Weston and Bogert....	14

APPENDIX I

REFERENCES

1. Field Manuals (FM)

FM 5-5	Engineer Troop Units
FM 5-15	Field Fortifications
FM 5-20	Camouflage
FM 5-22	Camouflage Materials
FM 5-25	Explosives and Demolitions
FM 5-31	Use and Installation of Boobytraps
FM 5-34	Engineer Field Data
FM 5-36	Route Reconnaissance and Classification
FM 20-32	Land Mine Warfare
FM 21-10	Military Sanitation
FM 27-10	The Law of Land Warfare
FM 101-10	Staff Officers' Field Manual: Organization, Technical, and Logistical Data.
(S) FM 101-31	Staff Officers' Field Manual: Nuclear Weapons Employment (U).

2. Technical Manuals (TM)

TM 5-220	Passage of Obstacles Other Than Minefields
TM 5-232	Elements of Surveying
TM 5-233	Construction Surveying
TM 5-234	Topographic Surveying
TM 5-235	Special Surveys
TM 5-250	Roads and Airfields
TM 5-251	Army Airfields and Heliports
TM 5-252	Use of Road and Airfield Construction Equipment
TM 5-260	Principles of Bridging
TM 5-270	Cableways and Tramways
TM 5-271	Light Stream-Crossing Equipment
TM 5-272	Widened Steel Treadway Bridge
TM 5-277	Panel Bridge, Bailey Type, M2
TM 5-285	Semipermanent Highway Steel Bridges, 30-, 60-, and 90-Foot Spans.
TM 5-286	Semipermanent Highway and Railway Trestle Bridges.
TM 5-295	Military Water Supply
TM 5-297	Wells

TM 5-301	Engineer Functional Components System Staff Tables of Installations, Facilities, and Equipages.
TM 5-302	Construction in the Theater of Operations
(O) TM 5-310	Military Protective Construction
TM 5-351	Gas Generating
TM 5-370	Railroad Construction
TM 5-371	I-Beam Railway Bridge
TM 5-372	Unit Construction Railway Bridge
TM 5-373	Through Truss Railway Bridges
TM 5-541	Control of Soils in Military Construction
TM 5-634	Refuse Collection and Disposals; Repairs and Utilities.
TM 5-665	Operation of Sewerage and Sewage Treatment Facilities at Fixed Army Installations.
TM 5-666	Inspections and Preventive Maintenance Services, Sewage Treatment Plants and Sewer Systems at Fixed Installations.
TM 5-680	Electrical Facilities, General, Engineering, Data and Practices, Tools and Equipment, and Safety Practices, Repairs and Utilities.
TM 5-681	Preventive Maintenance for Electrical Facilities
TM 5-704	Construction Print Reading in the Field
TM 5-760	Electrical Wiring
TM 5-765	Electric Power Transmission and Distribution
TM 5-766	Electric Power Generation in the Field
TM 9-1910	Military Explosives
TM 9-1946	Demolition Materials
TM 19-500	Enemy Prisoners of War
(C) TM 23-200	Capabilities of Atomic Weapons (U)
TM 38-230	Preservation, Packaging, and Packing of Military Supplies and Equipment.

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For explanation of abbreviations used, see AR 320-50.

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